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THE STARS & THEIR MYSTERIES

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AN AURORA BOREALIS.

This beautifully coloured drapery, which seems to be suspended from the sky, is in reality in our own atmosphere. It is due to a movement of electricity in the upper regions of the great ocean of air which surrounds this planet Earth upon which we live.

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THE STARS AND THEIR MYSTERIES

AN INTERESTINGLY WRITTEN ACCOUNT OF THE WONDERS OF ASTRONOMY, TOLD IN SIMPLE LANGUAGE

BY

CHARLES R. GIBSON, F.R.S.E.

AUTHOR OF
"OUR GOOD SLAVE ELECTRICITY"
"THE GREAT BALL ON WHICH WE LIVE"
"HEROES OF THE SCIENTIFIC WORLD"
&c., &c.

WITH 19 ILLUSTRATIONS & DIAGRAMS

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TO

RUTH, GEORGE, CONNIE

AND TO

ALL BOYS AND GIRLS

BETWEEN THE AGES OF NINE AND FOURTEEN

YEARS

AND TO ALL WHO WISH TO HEAR ABOUT

THE SUN, THE MOON, AND

THE STARS

PREFACE

THIS volume is one of the "Science for Children" series, each volume of which is complete in itself. The author has endeavoured to treat the subject of Astronomy in a realistic fashion. Instead of merely relating what has been discovered about the Moon and the Planets, we make an imaginary trip in a wonderful flying machine, and see for ourselves what these heavenly bodies are like. Of course the sights which we see are the realities. At other times we make simple experiments which explain to us the behaviour of the Sun and the Moon. The whole subject is treated in the easy-going, yet accurate, style already found acceptable in *The Great Ball on which we live* and *Our Good Slave Electricity.*

The author is indebted to his friends, Donald M'Lean, F.R.A.S., Observer and Curator of the Coats' Observatory, Paisley, and Professor James Muir, D.Sc., M.A., of Glasgow, for kindly reading the proof sheets of this volume.

June 1915.

AUTHOR'S NOTE

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CHAPTER I

A TRIP TO THE MOON

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A TRIP TO THE MOON

WHEN we were very young we had a nursery rhyme which told of an old witch who rode away up on a broomstick to sweep the cobwebs from the sky. Of course we understood that it was just a nonsense rhyme, written for the amusement of children. But you know that nowadays people can really fly up in the air, not on broomsticks, but on aeroplanes which have engines and propellers to drive them along.

I have watched a man, on an aeroplane, climb right up towards the sky until he was lost to sight in the clouds. But we can never hope to fly to the Moon. Why not? For very many reasons, one of which is that the air only goes up a comparatively short distance.

But suppose we agree to make a trip, in our imagination, right away up into the sky till we reach the Moon! You know how easy it is to do wonderful things in your imagination! We

shall suppose we have a machine that does not require air in which to fly, and that we can live very comfortably in an enclosed cabin attached to this wonderful flying machine.

At what speed are we going to make our machine fly ? Some aeroplanes have travelled as much as one hundred miles in an hour, but that speed will be far too slow for us, because we have such great distances to go.

Flying at one hundred miles per hour, we should not reach the Moon for three months. And the Moon is our nearest neighbour in space. The Sun is four hundred times as far away as the Moon, so it would take us a hundred years to reach the Sun. And even this far-distant Sun seems a near neighbour when we think of the distance from us to the fixed stars. To reach the nearest of the stars it would take us millions of years. I am not going to ask you to imagine yourself living for millions of years, shut up in the cabin of our flying machine. It is quite evident that we must increase the speed of our machine. Suppose we make it go as fast as a ray of Light can travel! How fast is that ?

Long, long ago an Italian astronomer, named

Galileo, tried to find out the speed at which Light travelled. His idea was to watch how long the light of a lantern would take to go from one mountain-top to another. He sent a friend, with a large lantern, to the top of a high mountain, while he himself climbed another mountain, taking a lantern with him also.

But how was Galileo to know when the light left the distant mountain?—he would only see it when it arrived at his mountain. They had no watches in those days, and clocks were very poor timekeepers, but Galileo got over the difficulty in the following manner.

Galileo had told his friend to keep his lantern covered until he saw the light suddenly shine out from Galileo's lantern. On the arrival of the light from Galileo's lantern, his friend was to snatch the cover off his own lantern. Galileo would then see how long it took Light to travel to his friend and back again, allowing for the time occupied by his friend pulling the cover off his lantern. What did Galileo find? At what speed did the light travel? Galileo said that it took no time at all. Of course he was wrong; Light must take *some* time to travel from one place to another. But it was a long,

long time before anyone could find out the speed of Light. We shall have a talk about that some other time. Meantime we wish to know at what speed Light does travel.

If I speak of a person walking at the rate of four miles per hour, or of a boy cycling at the rate of ten miles per hour, or of a motor car travelling at forty miles per hour, or of an express train travelling at sixty miles per hour, you can form some idea of these different speeds. Even when I speak of a flying machine going at the rate of one hundred miles an hour, you have an idea of what that speed must be. But when I tell you that Light travels at one hundred and eighty-six thousand miles per second, you cannot picture such a speed. To tell you that it is equal to eleven million miles per minute, or nearly seven hundred million miles per hour, does not help you. The speed is quite unthinkable.

The speed of Light is so great that any race we set for it on this Earth seems no time at all. You know that it takes us several months to travel round this World in a steamer. Of course we could go far faster in a flying machine. But even if we could keep flying all the time

at one hundred miles per hour, it would take us ten days.

Suppose now that it were possible to send a ray of light on this same journey around the World. It would have travelled right round before you could count " one." Indeed it could travel five hundred times round the World in one minute. That may help to give you some vague sort of idea of the speed at which our flying machine is to travel.

Even at this unthinkable speed, it would take us about four years to reach the nearest star. Does it really take Light several years to travel from a star to us? It does; it takes Light hundreds of years to reach us from some of the distant stars. If one of these far-distant stars should disappear suddenly, you and I would know nothing about the change. When we looked up into the sky we should still see the star shining away year after year. Our children and our grandchildren would still believe the star to be where it had been always, for the last rays of light, sent out by the star before it disappeared, would take hundreds of years to reach this World. There is no hope of our ever reaching these very distant stars in our imaginary

flying machine; it would be too big a tax on our imagination to live in the cabin of our machine for hundreds of years.

For the present we shall be content with a trip to the Moon. But one boy says that he cannot imagine our flying machine forcing its way through the air at the enormous speed at which Light travels. Even when travelling by motor car, at the comparative snail-pace of, say, forty miles per hour, we have to see that hats and veils are well fastened on, or they will be snatched from us by the air as we force our way through it. This boy says that he has been told that a good deal of the additional energy required to drive a train at sixty miles an hour is used up in forcing the train through the ocean of air.

We quite agree with this boy that it would be very difficult to imagine our machine travelling through the air at the speed of Light. We shall get over this difficulty by making our machine not exceed one hundred miles per hour so long as we are in the ocean of air. When we get beyond this great blanket of air, we can increase our speed to that of Light.

I am very glad that we have come to this

arrangement, for I had just been thinking that our journey to the Moon would be a very disappointing one, as it would have taken only about one second to get there. Now our journey will be very much slower and we shall have time to look about us as we fly upwards.

Before setting off, I wish you to notice two instruments which have been fixed outside one of the large windows of our cabin. You say that one is a thermometer, and that the other is a weather-glass. When I ask what these instruments are for, you have no difficulty in telling that the thermometer is to show us whether it becomes warmer or colder as we fly upwards. And what about the weather-glass? You say that it is to tell us whether we shall have good or bad weather on our journey. But you are wrong. You forget that rain and snow and hail can exist only between the clouds and the Earth. There cannot be any rain above the clouds; all will be sunshine there. As we shall take only a "jiffy" to reach the clouds and get above them, any changes of weather will not worry us. Why then have I troubled to fix a weather-glass outside our window?

The correct name for a so-called weather-glass

is a *barometer*, and if you take the trouble to look up your dictionary, you will find that this English word *barometer* has been made out of two Greek words which mean weight and measure. A barometer is an instrument for measuring the weight of the air pressing upon it.

The barometer which we are taking with us is one of the old-fashioned kind having a long tube with mercury in it. The more the air presses upon the mercury the higher is it forced up the tube, and the less the pressure of the air the lower does the mercury fall in the tube.

But what has that to do with the weather? Well, it so happens that when the mercury is falling in the tube we are likely to have rain. One reason for this is that the air tends to move in to places at which the pressure is lower, so that the air at such places is pushed upwards. This cools the air, as you shall see presently, and the water-vapour carried in the air also cools and condenses into rain-drops. And this is the reason why, when we are about to set out on a holiday, even though the glass may be standing high we are advised to take our waterproof coats with us; we are likely to have rain.

But sometimes it does not rain when the glass is low, and at other times it does rain when the glass is high. The weather in the British Isles is very difficult to predict with certainty even a few hours ahead. What I wish you to notice is that it is only the pressure of the air that a barometer can measure. If we place a barometer under a glass cover and pump out some of the air, we can make the mercury fall at once.

Now you see why we are taking this barometer with us; we are going to watch how the pressure of the air alters as we fly upwards. At present the mercury in the barometer tube stands about thirty inches in height.

The mercury in our thermometer tube comes up from a small glass bulb, the tube and the bulb being made in one piece. When the mercury becomes hotter it will expand, and when it becomes colder it will contract. When it expands it will rise farther up the tube, and when it contracts it will fall lower in the tube. At present it stands at 55° on Fahrenheit's scale; it happens to be a good September day. There are some banks of clouds overhead, so that we cannot see the Sun as

we set out on this great expedition to the Moon.

We all get comfortably settled in the enclosed cabin of this wonderful flying machine which we have made in our imagination. Off we go at the rate of one hundred miles per hour. We have only time to take a hurried look at the barometer before we enter the clouds, but we notice that the mercury has fallen several inches already.

When we emerge from the misty clouds we cannot see the instruments for the moisture on the window. By the time it clears we are about two miles upwards off the Earth. We find that the temperature has fallen down below freezing-point. We are rather surprised, as it looks lovely and warm in the sunshine. The moment we shoot above the clouds we are out in the open sunshine, with all the sea of clouds below us. Our thermometer is placed in the shade, so that the direct rays of the Sun cannot reach it, as we wish to know the temperature of the surrounding air. We can see the mercury in the barometer is falling also, the higher we go.

One boy says that he thought it would be

warmer here, as we have climbed nearer to the Sun. It is true that we have travelled towards the Sun, but how much nearer have we got? If you were setting out from Great Britain to Australia, and if you took one step forward in the right direction, you might say that you were then nearer to Australia. The few miles we have mounted towards the Sun are no more in proportion than the one step towards Australia.

The reason why it is colder here than down on the surface of the Earth is that we have climbed out of the thickest part of the great blanket of air which serves to keep the Earth warm, just as your blankets keep you warm. The air is what you might describe as much thicker near the Earth, but, to speak more correctly, we should say that the air is much denser at the surface of the Earth. Up here it is much flimsier.

One girl says that she climbed a high mountain with her father, on a beautiful summer day, and it was so cold on the top of the mountain they could not stay there many minutes.

While we have been talking about those things, our flying machine has carried us

upwards many miles, and when we look out at our instruments we find that the mercury has frozen, and we cannot get any further information from them. But men have sent captive balloons up into the air, carrying with them other instruments suitable for recording very low temperatures, and these instruments, after being raised to a height of ten miles, have recorded 100° of frost.

In Great Britain we seldom have a temperature as low as 40° of frost, but in Siberia the temperature near the ground is often as low as 100° of frost.

We keep rushing upwards and in half-an-hour we know that we must be about fifty miles from the Earth, as we have been travelling at the rate of one hundred miles per hour.

The air at this height is so rare that we could not possibly live in it. It is a good thing that we are in an enclosed cabin, and that we have plenty of fresh air in liquid form, which keeps giving off ordinary air just at the rate we require it.

We know that in about an hour and a half we should be clear of the atmosphere altogether, and that we may travel thereafter at the speed

of Light, which means about eleven million miles per minute.

One little girl says she is feeling very sleepy, and as she was too excited to sleep much last night, I advise her to lie down and have a sleep now; we shall waken her when we arrive at the Moon.

CHAPTER II

AN ALARMING ADVENTURE

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AN ALARMING ADVENTURE

IT is well that our excitable little friend is fast asleep, for while we are trying to guess where the beautiful blue sky has gone, we are alarmed to see a great flare of light rush past us. No one speaks for a moment.

Then one boy says that it must have been lightning very close to us, but he forgets that lightning can only take place between one cloud and another, or between a cloud and the Earth, and we are far away up beyond the clouds. One girl suggests that it was much more like some great rocket thrown by a giant, though we are all past the stage of believing in giants. What was this flaring thing which flew past us so quickly ?

It was a meteor. But what is a meteor ? Of what is it made ? It is composed of just such materials as we find on the Earth ; chiefly stone and iron. One little girl says that she hopes the meteor will not fall near her home ;

it might kill someone. But she is quite satisfied when I assure her that this meteor will never reach the Earth.

It was certainly making straight for the Earth as it flew past us, but see how hot it had become in forcing its way through the air. On entering the denser air below us the meteor would be melted and boiled away to nothing but a gas or vapour. When this vapour cooled again it would become very fine dust, which would float about in the air for a long time before falling to the ground.

What does a meteor look like ? You will be surprised when I tell you that it was certainly not any larger than a pebble, and may not have been any bigger than a pea. No one has ever seen one of these meteors, for they disappear as soon as they enter our atmosphere. How then can we tell their size ? Because astronomers have estimated what size they must be from the manner in which they behave. Sometimes the estimations have shown them to be as small as a pin-head, while on other occasions astronomers have likened certain meteors to grains of dust. We should never have known of the existence of meteors except

for the brilliant flare of light produced by them.

One boy asks if it is not possible that what we saw was in reality a falling star, or what is often called a shooting star. Some of the young folk laugh at the idea, but the boy is quite right. A shooting star is just one of those small meteors flying into our ocean of air. Of course the people who gave these the name of shooting stars did really believe that these were stars.

Seven hundred years ago the Egyptians wrote down a description of a very alarming occurrence. They said that the stars were seen to fly about like grasshoppers. What they saw really was an excellent shower of meteors. You may have seen a shower of shooting stars in August, or more likely about the middle of November, but what the Egyptians saw was something much more beautiful than that. There have been no really great displays of meteors since you and I were born, but about fifty years ago there was a very beautiful display. It was on the thirteenth day of November in the year 1866.

Astronomers were on the look-out for the arrival of this display, and it appeared just

when they expected it. But how did they know to expect it? Because just thirty-three years previously there had been a grand display, and thirty-three years before that time there had been another great shower, and thirty-three years before that there had been another, and so on. It looked as though we were meeting the same swarm of meteors once in every thirty-three years, and that some of the swarm succeeded in entering our atmosphere as we rushed across their track. Indeed it became evident that there was some gigantic swarm of meteors travelling through space around the Sun, and that somehow or other we happen to cross their path once in every thirty-three years.

In the year 1833 the shower of meteors was so very bright that many people in America were wakened from their night's sleep by the blaze of light. Out on the plantations the negroes rushed into the open air and threw themselves on the ground, crying for mercy. It seemed to them as though the end of the world had come. The stars were falling in thousands; it was just like a rain of fire in the sky.

In Great Britain this 1833 display was well seen, and naturally the astronomers were ready

for the return of the swarm due at the end of the next thirty-three years, which was November of 1866. The meteors did return, or, in other words, we met them again in our journey through space. The display on this occasion was grand, but not nearly so grand as it had been thirty-three years previously.

You could calculate for yourself when the Earth was due to meet this swarm of meteors again. You have just to add thirty-three to 1866 and you can foretell the date of the next display as 1899. But the Earth failed to meet the great swarm in 1899. We met some stragglers, as we do every November, but we did not meet the great swarm at the usual meeting-place.

We may picture the meeting of the Earth and the swarm as something like the diagram on page 40.

You see what a great big race-course the meteors have to go round. It takes the great swarm or cluster of meteors thirty-three years to go once round the complete course, but there are stragglers all along the race-course, and all are travelling around the Sun.

Looking at the drawing, you see how small

the Earth's race-course is when compared with that of the meteors. You see that the Sun is in the centre of our course, which is very nearly

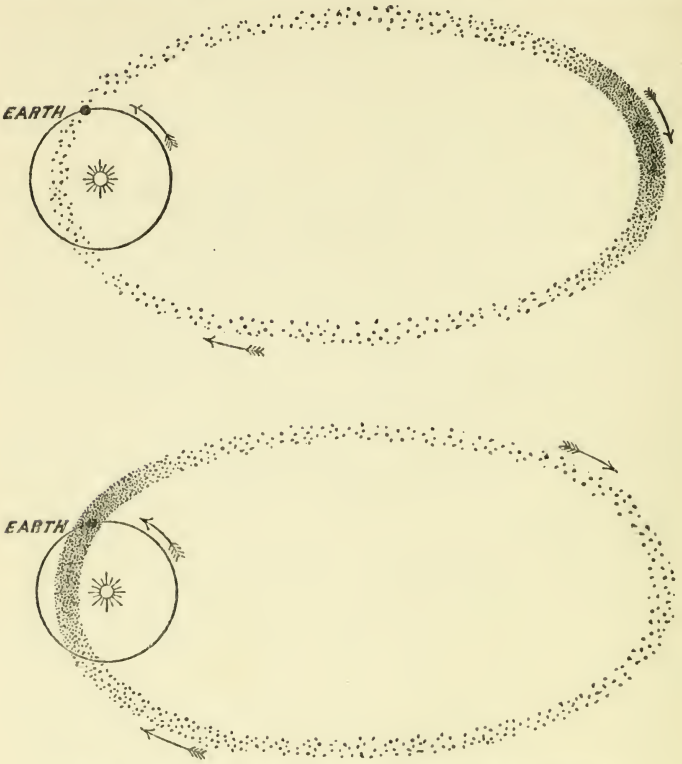

FIG. 1.—The Earth passing through a swarm of meteors

circular, but look what an oval-shaped course the meteors have to travel, and you will note also that the Sun is very near one end of this giant race-course. It happens the Earth will

cross the meteors' course once every year. This happens to be in November, and on each occasion some of the meteors, which I have described as stragglers, will enter the Earth's atmosphere. But when the great swarm of meteors happens to be at the meeting-place then we have one of those grand displays already described. This will take place once in every thirty-three years, and astronomers came to depend upon this regular occurrence.

You will all be young men and women by the time the next great shower is due in 1932, but you must not expect such a grand display as was seen in 1833. It seems clear that the great swarm is getting more scattered.

We shall see later that a great comet used to travel round this same race-course on which we now find meteors, and we believe that the meteors are just the materials of which the comet used to be made up. When the comet disappeared it evidently broke up into those very small fragments which we call meteors. Of course we should never have known anything about these meteors unless they happened to dive into our atmosphere and thus meet their fate by being burnt up as already described.

We shall have a talk about comets when we get back to the Earth. We have been flying upwards now for nearly two hours, and in a few minutes we should be beyond the boundary of our atmosphere. We feel sure that this ocean of air does not go higher than two hundred miles, if, indeed, it reaches that height.

One boy has another puzzle for me. If no one has ever seen one of these small meteors, how can we tell that they are made chiefly of stone and iron? That is quite a sensible question, and fortunately it is easily answered. Although none of these tiny meteors can ever reach the Earth, there are great big lumps of material which have fallen from the sky right on to the Earth. We call these sky-stones "meteorites." Perhaps you think from this name that a meteorite ought to be a smaller thing than a meteor. I remember that was how it occurred to me when I was your age. But it is quite the other way about; while a meteor is not larger than a pebble, some meteorites weigh many tons. There is really no need for the two names meteor and meteorite; at first it was thought they came from different sources.

AN ALARMING ADVENTURE

If you ever visit New York you may see a great meteorite in the Natural History Museum there. I need hardly say that this huge meteorite did not fall into the Museum; it would have done terrible destruction if it had. It did not even fall in America. It came to Earth in Greenland, the land of the Eskimos, and when the illustrious Arctic explorer, Peary, saw it there, he had it conveyed to New York, so that other people might see it. But did Peary really see it fall from the sky? He did not, nor did any of the Eskimos. How then can we be sure that it is really a meteorite? Because it was found in the ice in a great ice-field, and the only way in which it could have got there was by falling from the sky.

There were many stones which the ancients declared had fallen from above. They worshipped these stones, some of which were said to have been flung down by their imaginary god, Jupiter. But men of science did not believe in these sky-stones until about one hundred years ago. Then they could not help believing in them, for people actually saw one fall in France.

It came about in this way. The people saw

a great fire-ball flying through the air, when all at once it exploded with a terrific noise, and a shower of fragments of the great ball fell to the ground. Some of these pieces, weighing twenty pounds, were picked up still smoking. There could be no possible doubt whence these had come.

About forty years ago a similar fire-ball was seen in France, and on this occasion a large piece of rock and iron, heavier than yourself, struck the Earth with such force that it made a hole five feet deep in the ground.

When people were convinced that it was possible for stones to fall from the sky they kept a good look-out for any similar occurrences. The result is that we have a great collection of meteorites in the British Museum in London, and more than three hundred of these have been seen to fall from the sky. Some of those are large, and others are small.

On one occasion a meteorite fell quite close to a labourer while he was at work. On another occasion a meteorite fell right between two carters who were walking along a road. One day a lady was startled by a meteorite falling beside her while she was sitting in her garden.

On another occasion a child at play was alarmed by one of these stones falling down from the sky.

Why do we not fit up a great wire-netting overhead to protect us from these sky-stones? Because it would be quite ridiculous to take such precautions. So far as we know, no person in Great Britain has ever been killed or even struck by a falling meteorite. Nearly one hundred years ago a native of India was killed by a meteorite, and it is recorded that away back six hundred years before the time of Christ ten Chinamen were killed, and several chariots smashed, by a huge sky-stone. But to think of protecting ourselves against the possible fall of meteorites would be as ridiculous as though we were to build high barricades around our homes lest a lion might escape from some menagerie.

All the meteorites which we have found are made of rock-material, or a mixture of rock-material and iron and another metal called nickel. You know how we have plenty of iron on the Earth, and how we find it mixed with rock-material, and you know that a large part of our planet is formed of such material. We

also find nickel in the Earth, but not in such large quantities as iron. You know how this nickel is used for plating your bicycle handle-bars and such-like things.

Occasionally we find other things contained in these meteorites. There was one very remarkable meteorite, which fell in Australia, and which was found to contain no less than twenty-three different simple substances. Not only was there iron and nickel, but copper and gold, and aluminium, and platinum, and sulphur, and other sixteen different substances.

Some of the meteorites which fell in Mexico long, long ago were so rich in iron that the people have used the iron for making many things. This supply lasted them for very many years.

In India there was an emperor, who lived about three hundred years ago, and who had a sword made out of the iron found in one of those meteorites which had fallen in his country.

The strangest thing that has been found in a meteorite is real diamonds. But you would not be very rich if you possessed these diamonds, nor would they be admired if they were set in a ring or in a brooch. Why not ? Because

they are so very small that you could not see them except with a microscope.

We have been talking about meteorites which are large enough to reach the Earth. There is no doubt as to the materials of which they are made. We may take it for granted that the tiny meteors, which rush into our atmosphere and are converted into dust, are made of the same materials as the meteorites. We have seen that the meteors are probably pieces of some comet which has become broken. There is really no distinction between meteors and meteorites.

While we have been talking about meteors and meteorites, we have been climbing up out of the atmosphere in our imaginary flying machine. As we have been on this upward journey for fully two hours we ought to be quite clear of the ocean of air.

We can go safely full steam ahead to the Moon now. We have only travelled about two hundred miles and we have more than two hundred thousand miles to travel yet before we reach the Moon, but now we can go at the speed of Light, and you remember how quick that is! Light travels nearly two hundred thousand

miles per second, so we shall be at the Moon in about one second after switching on full speed.

We shall have no time to talk on this journey, so any questions had better be asked now. One boy wishes to know if astronomers can see these meteors flying through space far out where there is no air with which they may collide. Some astronomers did think at one time that they had seen meteors cross over the face of the Moon, on which they appeared as small dark objects. They called these *dark meteors*, but later on it was suggested that what the astronomers had really seen was merely particles of dust falling inside their telescopes. It was found that by gently tapping the telescope, while looking at the Moon, small particles of black dust could be dislodged from the inside of the telescope tube, and these objects looked exactly like the "dark meteors" reported by the astronomers. Meteors are very much too small to be seen away up in space even with the best telescopes. Even when they reach our atmosphere we do not see the meteors themselves, we see only the flare of light produced by their burning away.

A girl has a question to ask also. If swarms

of meteors enter our atmosphere and become dust which falls down on the Earth, will that dust not go to make the Earth bigger and bigger? We believe that millions of these small meteors are trapped by the Earth's atmosphere every day of the year, and some astronomers do think that the Earth has really grown a great deal larger by the addition of this meteoric dust falling for countless ages. But other astronomers say that it would take a million million years before one inch could be added to the size of the Earth by the fall of such dust.

We have no time for further questions at present; we are anxious to reach the Moon. We turn to our right hand and there is the Moon, looking very much brighter than usual, because there is no air between it and us, and also because the sky is jet-black. It is only the half-moon which is shining, and its size looks very much as we see it from the surface of the Earth.

One boy reminds me that I have never explained where all the beautiful blue sky has gone, but we must talk about that when we get to the Moon.

When I switch on full speed we are at the Moon before you could count ten.

CHAPTER III

WHAT THE MOON REALLY IS

CHAPTER III

WHAT THE MOON REALLY IS

ONE day a little girl of five years of age asked me to read to her from one of her nursery-books. We came to a rhyme entitled "The Moon's Adventure," which has been reproduced for you on page 54.

You see that the little boy and girl watched the Moon caught in their willow-tree, and how it only got free by the wind shaking the tree, and how the Moon got its face scratched. You will notice that the last verse says :

> "So now you know the reason why
> His face is scratched from chin to eye.
> It's truly true what I tell you,
> Bob saw it happen, so did I."

When the reading of the story was finished, I asked the little girl if the Moon did really get caught in the tree, whereupon she replied in a very emphatic manner : "Of course it did !"

When I told her that the Moon was thousands and thousands of miles away up in the sky,

and that it could not possibly come near the willow-tree, she said: "Well, it was true in the story, for that book" (it was called *Sunday*) "would not tell fibs." Then she told me about a boy who buried a book in the garden because it did tell fibs. These were the thoughts of a little girl of five years of age. When I ask boys and girls of twice her age if they can tell me of what the Moon is made, they generally say that they do not know.

Imagine then that we have arrived at the Moon in that wonderful flying machine of which I was telling you in the preceding chapter. We cruise quietly about, looking down on the Moon. It looks like our own world, "the Earth," only there is nothing growing on it; it seems to be all bare rocks. But the mountains look very high; some of them are really higher than the highest mountains on the Earth.

Most of the children in our cabin say that they thought the Moon was quite smooth, and had a sort of polished surface. When they were told that the Moon did not send out light, but merely reflected the light of the Sun, they pictured some sort of mirror-like surface.

We are startled by a sudden cry of surprise

THE MOON'S ADVENTURE

Last night we lay awake to creep
Like mousies from our beds, and peep
  Into the lane through the window-pane,
When all the world had gone to sleep.

And there we saw—oh dear, dear me!—
The moon caught in our willow-tree,
  And when he tried away to glide,
It scratched his face so dreadfully.

The willow wanted him to stay;
The moon just ached to get away.
  It was no use—he couldn't loose
The arms that held him back to play.

The soooo-ing wind got angry then,
And she came rushing from her den,
  And shook the tree most dreadfully,
And set the old moon free again.

So now you know the reason why
His face is scratched from chin to eye.
  It's truly true what I tell you
Bob saw it happen, so did I

THE MOON'S ADVENTURE

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behind us; the little girl who was sleeping has wakened up and, looking out of the window behind us, she calls: "Oh! look how huge the Moon has grown; it is far, far bigger than the Sun!"

Looking out at her window, we see what does look like a giant moon. But our little friend is very much surprised when I tell her that that is old Mother Earth, and that the rocky mountains close to us are part of the Moon. But how can the Earth shine like the Moon? In exactly the same way as the Moon shines; both merely reflect the light sent out by the Sun.

We can scarcely believe that this "huge half-moon," standing out so clearly against a jet-black sky, is really the Earth which we left a few hours ago in broad daylight. But the people on the part of it which we speak of as shining like the Moon are still in broad daylight. Those people living on the half of the great globe which appears dark to us are in darkness except for the light which is reaching them from this Moon up here where we are at present.

One boy says that some of the astronomers on the Earth may be looking at us through their

telescopes, and he starts making Boy Scout signals with his arms. He is disappointed when I tell him that the very best telescope on Earth would not enable the astronomers to see our flying machine even as a speck on the face of the Moon. If our machine had been as big as one of our great cathedrals, it could then have been seen as a tiny dot.

But we cannot help staring at that great ball on which we live, and which we left so recently. This distant view gives us a good idea of how much bigger the Earth is than the Moon. Of course if you look down at the Moon at present you can get no idea of its size; you can only see a small part of it, just as you could only see a small part of the Earth until you made this imaginary voyage skywards. But you can remember what the Moon looked like when you saw it from the Earth.

Looking back now at the far-distant Earth, you would say that it was much more than four times the size of the Moon. It is really only four times bigger round the waist, but that is a greater difference than you might suppose at first. I can remember the time when many foolish young ladies seemed to vie with one

another which of them would have the smallest waist. But even the largest waist of the present day is not four times that of those foolish days. Here is a picture of the waist-belts that would fit two young ladies, one of whom had a waist four times that of the other.

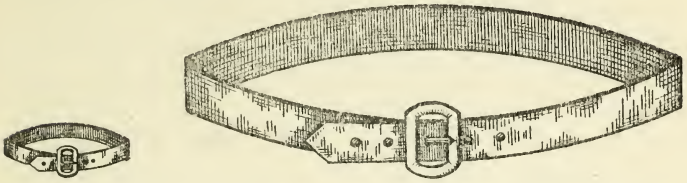


FIG. 2.—The large waist-belt is just four times bigger than the smaller one

But even this measurement does not give you a very good idea of the actual difference in size between the Earth and the Moon. Suppose we make two square boxes, one of which has a waist measurement four times that of the other. This is what they would look like (see Fig. 3, p. 58).

If, before showing you this picture, I had asked you how many of the smaller boxes we could pack into a box four times larger, you might have said that the larger box would hold four of the smaller ones. But if you took time to think about it you would see that it

would hold far more than four. Let us make the experiment.

You see that we have been able to pack four rows of boxes, with sixteen boxes in each row or tier, and you know that four times sixteen

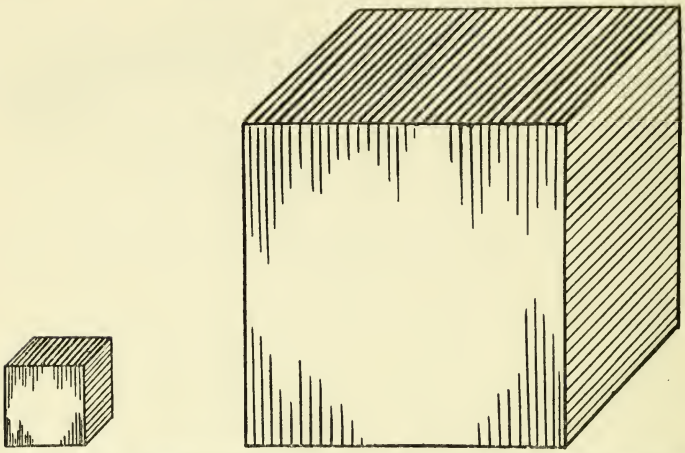


FIG. 3.—The larger box measures only four times greater than the smaller box does, round the waist

are sixty-four. But if the larger box can contain sixty-four of the smaller boxes then the large box must be sixty-four times larger than the smaller one! And so it is, although its waist measurement is only four times greater.

When we are comparing the sizes of the Earth and the Moon, and the other heavenly bodies, it is usual to speak of their diameters. The

word *diameter* is made out of two Greek words which mean *to measure through.* The diameter of the Moon or of the Earth is just the distance

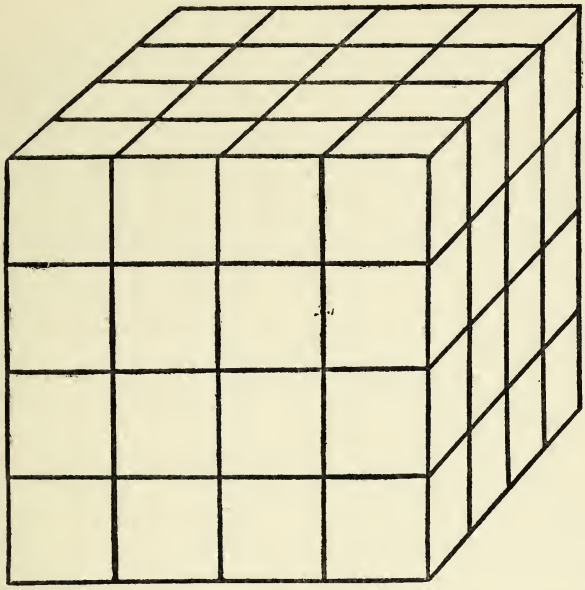


FIG. 4.—Here we see sixty-four of the smaller boxes packed into the larger box

right through the centre from one side to the other. We say that the diameter of the Earth is four times greater than the diameter of the Moon, but you know that the Earth could contain sixty-four Moons. Here is what the Earth and the Moon would look like if viewed from the same distance (see Fig. 5, p. 60).

You are still puzzling over the blackness of the sky! Where has all the beautiful blue sky gone? One boy guesses that the sky is still as blue as ever and that it only looks black

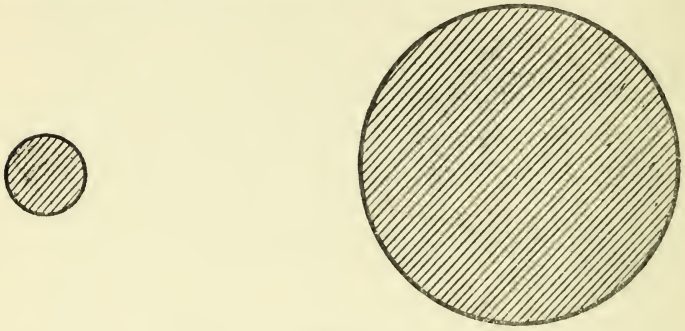


FIG. 5.

What the Moon looks like from the Earth

What the Earth would look like from the Moon

because the Sun is so very much brighter. The Sun certainly appears very much brighter; it is quite impossible to look directly at it, but that is not why the sky looks black. The Sun is brighter because there is no air between us and it to tone down its light. You know how easy it is to look right at the Sun on a morning when there is fog or mist about. The water particles in the air catch a lot of the Sun's light and diffuse it or scatter it. That same thing happens in a much lesser degree at all times; the Sun's light is diffused by the mois-

ture in the air. It is this same diffusing of the light which makes the sky appear blue to us.

And so the blue sky does not really exist; we are looking up into jet-black empty space, but the Sun's light is so scattered by our atmosphere that we appear to be surrounded by a great blue dome.

Looking out from our flying machine, we see a jet-black sky all around us, because there is no atmosphere up here to scatter the sunlight.

Suppose we take a quiet cruise about the Moon in our imaginary flying machine. One boy remarks that he is glad it is a fine day, for, although we cannot leave the cabin of our flying machine, we can see much better on a fine day. Another boy says he guesses that if we were to stay here for a hundred years it would be fine every day. He is quite right. There are no clouds around the Moon, and so there cannot be any rain.

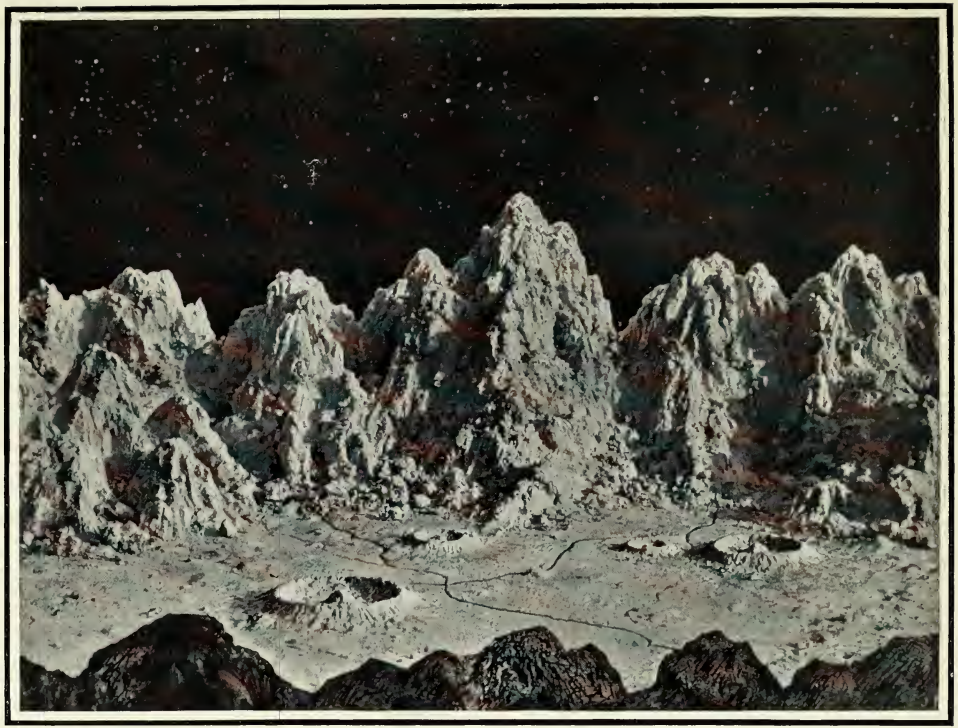
When we looked at the Moon from the Earth, the Moon's surface seemed to be beautifully smooth, but now that we have travelled to it in our flying machine we find it to be anything but smooth. It seems to be covered entirely

with high mountains, and great rings of mountains. One boy says that those large basins formed by the rings of mountains remind him of some mountains that he saw on the Earth, and that he was told the mountains had formed the crater of a great volcano in the long ago.

But what is a volcano ? Those of you who have read *The Great Ball on which we live* will remember that although a volcano is described often as a burning mountain, it is not really burning, but it has a large chimney in the centre of it reaching far down into the Earth. Great quantities of molten rock-material are hurled up this chimney while the volcano is active. There are a few active volcanoes on the Earth to-day, but there are traces of very many more that have long ceased to be active.

One boy hopes that we may find an active volcano as we cruise around the Moon, but he will be disappointed. The Moon is no longer a hot body like the Earth, and the Earth used to be very much hotter than at present, when there were a great many volcanoes at work.

Looking at the Moon, we can see that it must have been very hot at one time also ; it seems



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MOUNTAINS ON THE MOON

If we could really visit the Moon this is what we should see.

so covered with volcanic mountains that one ring sometimes overlaps another.

But what is this huge dark-coloured part of the Moon ? One boy guesses that it is a sea or a lake, and when I tell him that there is no water on the Moon he is very much surprised. He says that there must have been water at one time, for he has seen a map of the Moon, and it contained a lot of Latin names which his tutor told him meant the *Sea of Rains*, the *Sea of Tranquillity*, the *Lake of Dreams*, and so on.

No doubt the map which the boy saw was quite a correct map of the Moon, for we speak of those dark patches as seas and lakes, although we know now that no water exists, and probably never existed, on the Moon.

It is those great dark patches on the Moon which seem to form the man's face ; this dark patch which we are coming to is the one which forms his right eye. It is called the *Sea of Rains*.

How bright the mountains look in the sunshine, and how black their shadows are. That is because there is no air. Look also how very clearly you can see the far-distant mountain ranges. You can scarcely believe me when I

tell you that the mountains on either side of that great crater are more than one hundred miles apart. But do you not remember how the mountains on the Earth have appeared to us sometimes to be very much nearer than usual ? If you asked the reason for this, you were told that it was because the atmosphere happened to be particularly clear. Well ! here on the Moon we have no air at all and that is why we can see everything so very clearly.

One little girl says that she had been wondering why there is nothing growing on the Moon, but now she sees that not even grass, nor moss, nor heather could grow, seeing there is no air and no water. Not only are the mountains bare rock, but the whole surface of the land is the same.

CHAPTER IV

A STRANGE THING HAPPENS

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A STRANGE THING HAPPENS

AS we cruise around the Moon the scenery is so very monotonous that one of our little friends in the cabin goes forward to pick up a book to wile away the time. It is a book just about the size of this one which you are reading, but our young friend is surprised, when he lifts the book, to find that it is "almost as light as a feather." What has happened? The book looks just the same as it ever did.

Someone remembers seeing a set of scales and weights in a cupboard of our cabin, so we shall weigh the book to see how heavy it is really. The boy to whom the book belongs says that he knows the weight of the book, for he sent the same book by post a few days ago. It weighed one pound and a half before he parcelled it up. Everyone is sure that it does not weigh even half-a-pound now.

Here come the scales and the weights to decide the matter. The scales are of what you

might describe as the see-saw kind of balance. We try a half-pound weight on the one pan and the book on the other pan, but the book is heavier than that. Even a pound weight is too light, and we find that we require one pound and a half to balance the book. But it seems nonsense to say that the book weighs one and a half pounds; it feels only a few ounces.

One youthful philosopher of ten years of age takes the book in one hand and the one-and-a-half-pound weights in the other hand, and he says that the weights are just as light as the book. His verdict is that the scales are all right but the weights are all wrong.

While the young people are discussing this matter, I bring forward a weighing machine which requires no weights. It has only one large pan, which is supported by a spring. The object which is to be weighed is placed upon the pan, and presses down the spring, at the same time turning an indicator which acts like the hand of a clock, and points to the weight marked on a dial or clock-face. We place the mysterious book on the pan of this spring-balance, and the hand points to "4 oz.," which you know is

equal to one quarter of a pound. That is much more like the weight of the book.

Our young philosopher, who has been holding the one-and-a-half-pound weights in his hand, places them on the pan of this spring-balance when I lift the book. The hand points again to "4 oz.," whereas there ought to be twenty-four ounces in one and a half pounds. He says that he remembers weighing eighteen pennies and that they weighed almost exactly six ounces. So we pass the hat round until we have collected eighteen pennies. We put these in the pan of our spring-balance and we find that they only weigh one ounce. It is quite evident that things weigh six times more on the Earth than they do up here at the Moon.

I pull back a curtain and here we have one of those machines upon which we can weigh ourselves. I get on to these scales and the children laugh when I declare that I weigh only two stones. Then every one must try their weight. One little girl weighs only nine pounds; not too heavy to send by parcel post. She says that she really weighs four stones and two pounds. That is her weight when she is on the Earth, but nine pounds is her real weight

while she is at the Moon. But how can the weight of a person or a thing alter like this ?

That book which we weighed a little ago is just the same as it was a few hours ago when we set out from the Earth, and yet it weighed six times more on the Earth. One girl examines the book, and says that she cannot see how it is possible for the weight of the book to alter. But her difficulty is due to her thinking that the weight is something which belongs to the book. A book is *heavy* just because it is being pulled down by the Earth. But now that we are away from the Earth it is the Moon which is pulling the book towards it. It is quite evident that the Moon cannot pull the book with so much force as the Earth can. You would not expect a little fellow to pull anything with so much force as a big fellow. The Earth pulls the book towards it with six times the force that the Moon does.

It is well to keep in mind that the pulling is not done entirely by the Earth and by the Moon. The book also attracts the Earth and the Moon ; everything attracts every other thing, but the attraction of the Earth, or of the Moon, is so great that the smaller attraction

of the book does not get a chance of showing itself.

I think it will be clear to you all how it was that the see-saw balance told us that the book still weighed one and a half pounds. It was because the Moon pulled these weights with the same small force as it pulled the book, so that the one-and-a-half-pound weights still balanced the book. But when the Moon pulled the book, while it was on the spring-balance, the same small force was only able to move the indicator round one-sixth of the distance which the Earth could have moved it.

Now we are going to try some jumps along the cabin floor. The cabin is not long enough to try running jumps, so we must content ourselves jumping from a standing position. Here is a little girl who says she can jump three feet; she had the jump measured at school, but she fears that with so many onlookers she may not do quite so well. We clear a space for her; she looks very keen, quite determined to do her best. No one is more surprised than herself at the result of her jump; she jumped almost the full length of our cabin floor and it measures eighteen feet.

There is no mystery about this giant-like jump. When you jump, it is the Earth that pulls you down and prevents you going farther. Of course some boys and girls can jump farther than others, because they can put more energy into the jump. But as the Earth pulls with six times the force that the Moon does, the Earth brings you down to the ground six times sooner than the Moon does. This little girl says that she will surprise her schoolfellows when she tells them that she jumped a distance of eighteen feet from a standing position. Of course she will not be able to show them this performance unless they come to the Moon.

We take another look at the mountains of the Moon. One boy says that there must be some living thing on the Moon, for he saw quite distinctly some dark thing running down the mountain-side. It was just a lump of rock-material. But what set it off? One boy guesses it was the wind. But there can be no wind where there is no air. For the same reason the falling rock would make no noise, as sound is a disturbance in the air.

But how did this piece of rock move? It

had become cracked and loosened by the constant change of temperature between day and night. It is extremely hot in the day-time, as there is no air to act as a parasol. But the little girl who felt it cold on climbing a mountain with her father says that if the Moon has no blanket of air, why is it not very cold ? If you were lying in front of a roasting fire, you would not require blankets to keep you warm ; but when the fire was put out you would lose the heat very quickly ; you would feel the want of the blankets then very badly. And so the surface of the Moon is very hot while the Sun is shining upon it, which is all day long (we shall see presently what a long day the Moon has), but at night, when the same part of the Moon is turned away from the Sun, the Moon loses its heat very quickly and becomes intensely cold.

We turn our thermometer to the Sun and up goes the mercury to the very top of the glass tube. We are sorry that we brought an ordinary household thermometer which only registers up to 120° of Fahrenheit's scale. If we had had proper means of testing the temperature up here we might have recorded

a temperature equal to that of boiling water (212° Fahrenheit).

It is fortunate that the builder of our imaginary flying machine took care to use materials which do not allow the heat rays from the Sun to enter our cabin; we have it heated very comfortably from within. The builder took this precaution in case we might cruise near the Sun in our journey through space.

Looking back at that giant half-moon which is our own Earth, I tell you that we should see it take the form of a thin crescent, a nearly full moon, and a full moon, indeed we should see it behave exactly like the Moon, if we remained a whole day where we are. Why not wait a whole day at the Moon? Because we have neither sleeping accommodation nor food enough. We have biscuits and milk, and surely that would do us for one day, and we could easily go without sleep for one day! But we should have to stay one of the Moon's days, which means the time that it takes to turn round once. You know that our Earth turns round once in every twenty-four hours, but the Moon takes about seven hundred hours to

turn round once, and that is about thirty days. You know that the Moon circles round the Earth in one month of about thirty days, so that it only turns round once during its whole journey round the Earth, but I shall tell you all about that when we get back to the Earth.

It is quite evident that we need not think of staying up here during one of the Moon's days, so we take one last look at our faithful attendant, which accompanies our Earth constantly in our great journey around the Sun.

We are impressed with the great sameness of the Moon's scenery; it seems to be covered all over with volcanic mountains of all sizes. We were surprised at the heights of these mountains, but after seeing our little friend jump the length of the cabin floor, we can understand how the mountains come to be so very high. The pull of the Moon is so much less than that of the Earth that when a mountain was thrown up, owing to the Moon's great heat and disturbed condition within, the rock-material could be thrown to a far greater height than could have been done by a similar disturbance on the Earth.

Now we shall have to be very careful in

going home. If we were to let our flying machine go full steam ahead at the speed of Light all the way, we should have a very serious accident. Whenever we entered the Earth's atmosphere we should become a red-hot meteorite, and be burnt alive. But we need have no fear; the builder has placed a little instrument on the front of our flying machine, and as soon as any air presses on this very sensitive instrument it will shut off the driving-power at once, and switch us on to the comparative snail-pace of one hundred miles per hour.

Safely landed on the Earth, we are delighted to see the clear blue sky once more; it is ever so much nicer than a jet-black sky. Everything around us has a beautiful, soft appearance, with none of the ghost-like shadows which we saw on the Moon.

When you have had a rest I shall tell you about the different shapes in which we see the Moon.

CHAPTER V

ABOUT THE DIFFERENT SHAPES OF THE MOON

CHAPTER V

ABOUT THE DIFFERENT SHAPES OF THE MOON

"GOD has cut a big bit out of the Moon!" That is what a little philosopher, aged three years, said to me on one occasion.

We had been travelling by train into the country, and had arrived at our destination in the dark. It was the first occasion on which this three-year-old boy had seen the Moon in its crescent form. You know how it is shaped sometimes like a large slice of melon. When my little friend caught sight of the crescent moon he was quite alarmed. He had always pictured the Moon as a great round thing. What could have happened to it? The only possible solution of the problem to this little fellow was that the Creator had suddenly altered the shape of the Moon by cutting a big bit out of it.

The full-grown philosophers, or wise men, of long ago did think that the Moon actually altered in shape, but you and I know better.

When you were very, very young you may

have pictured beautiful fairies sitting on the crescent of the Moon. I have seen such pictures on post cards, but I think the would-be fairies were real live actresses, and the Moon upon which they sat was made probably of pasteboard.

Our visit to the Moon did not teach us anything about the different shapes of the Moon, as we could only see a small part of the Moon at any one time. While we were at the Moon the Earth looked like a great half-moon, and later on it would have appeared as a crescent, but while on the Earth we cannot hope to see it in these shapes ; we can only see a very little part of the Earth at one time.

The different shapes of the Moon are called its different phases. We say that the Moon is in a certain phase. This word sounds a little like *face*, but while *face* rhymes with *race*, *phase* rhymes with *raise*.

Here are the different phases of the Moon (see p. 81).

But what causes these different phases? One boy guesses that they are due to the Earth getting between the Sun and the Moon, and thus casting a shadow on the Moon, by cutting off some of the Sun's light. But he is

wrong, although what he suggests does really

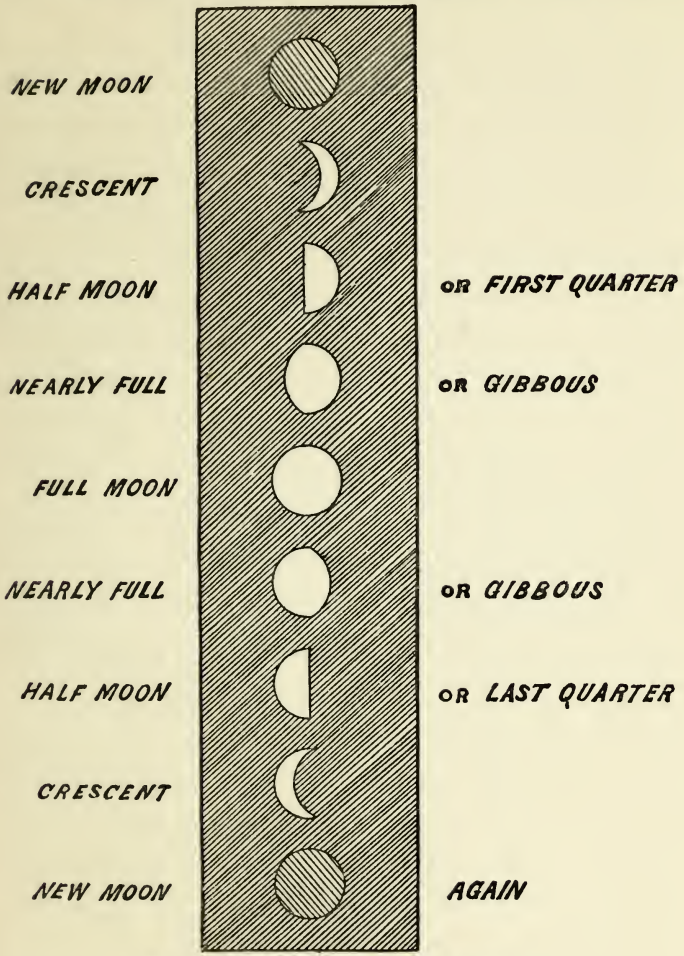


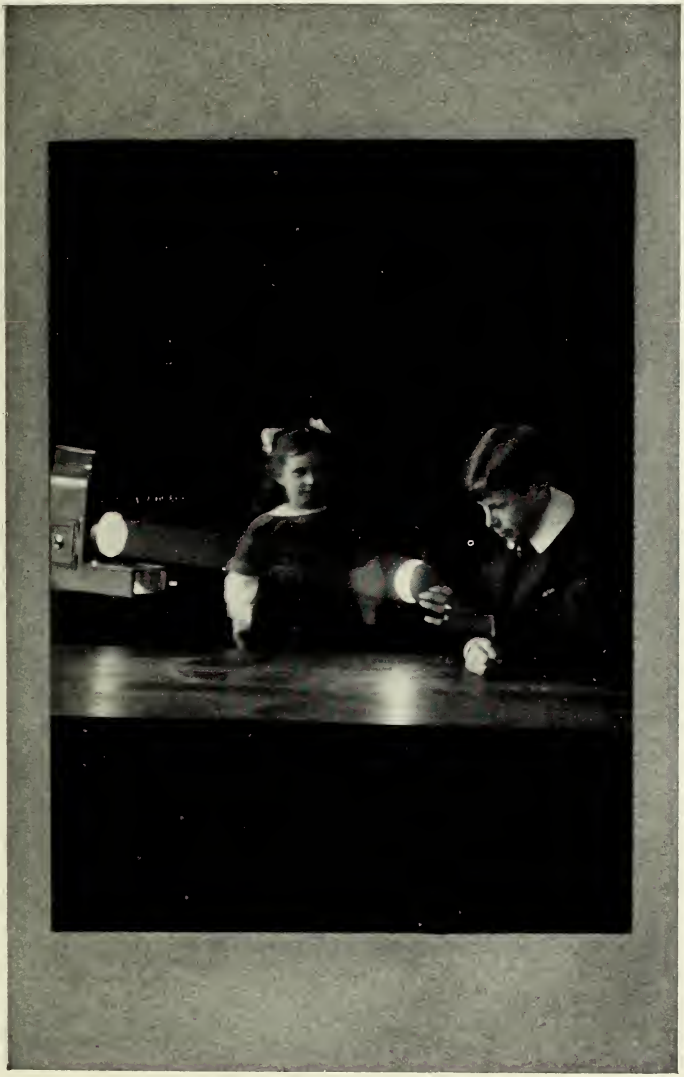
FIG. 6.—The different shapes of the Moon

happen occasionally. On these occasions, when

the Earth steps in between the Sun and the Moon, we do see the Moon as a thin crescent, but only for a very short time, as the shadow of the Earth crosses the face of the Moon. We call such occurrences *eclipses of the Moon*, but they have nothing to do with the regular phases through which the Moon passes continually.

There will be no mystery whatever about these different shapes of the Moon, if you will take the trouble to make a little experiment. All that you require for this experiment is a small electric lamp or torch and an orange. If there is no small electric lamp at hand, you may use a candle, and if you cannot find an orange, any round object or ball will do, so long as it is not black. The orange is to represent the Moon, and the lamp is to represent the Sun. But where is the Earth ?

We need not worry about the position of the Earth in this experiment, as the Earth plays no part in producing the different shapes of the Moon. You may place a stool, or chair, a few feet in front of the lamp, and take up your position on this imaginary Earth. The room must be quite dark except for the light coming from your lamp.



How to Imitate the Different Shapes of the Moon

This boy is holding a ball in the light of a lantern, and producing the different shapes of the Moon by altering the position of the ball, as explained on page 82.

As the imaginary moon (*the orange*) cannot stick up in space of itself, you must hold it between your fingers and your thumb, so that you can see the full face of the orange. The Moon is to circle around the Earth, so you will hold the orange at arm's-length and move it around yourself; the Sun, of course, remains stationary.

In moving the orange around you, it will be convenient to turn yourself round so that you are always watching the full face of the orange.

Suppose you commence the experiment by sitting with your back turned towards the lamp, and with the orange held in front of you but raised in the imaginary sky, so that the orange catches the full light of the lamp. You will see the full face of the orange lighted up, and you say that it is full moon. Then you commence to turn round very gradually towards the lamp, watching the miniature moon still held up in the sky. In a little you see the nearly full moon, and as you turn farther you see the half-moon. By this time you are sitting with the side of your face towards the lamp, and only one half of the face of the orange is lighted.

If you think of the whole orange, you would

say that only one quarter of the orange is visible to you. That is why the half-moon is also spoken of as the first quarter, or the last quarter, as marked in the drawing on page 81. When we speak of the half-moon, we are thinking of the face of the Moon, one half of which is lighted. When we speak of the first or last quarter, we are thinking of the whole Moon.

Continuing to turn towards the lamp, the half-moon gradually shades off into a thin crescent, just as seen in the drawing, and by the time the orange is passing above the lamp we fail to see its face altogether, and we say it is new moon.

Still carrying the miniature moon round on its circular journey, we soon see a small crescent of the orange lighted up. Then as it catches more of the light, we see the half-moon, which, of course, is the opposite half to the one we saw a moment ago. Then follows the nearly full moon, and once more we are back to where we set out from, and we see the full moon.

You will find it quite interesting to watch the real Moon going through its different phases. Suppose it happens to be new moon on the first evening upon which you commence your study

of our satellite. If you had never been told anything about the Moon, you might expect to see a beautifully bright full-faced moon. But you know that the new moon is quite the reverse of that; indeed you might have difficulty in finding out its whereabouts in the sky. It is a dark moon, but gradually a thin crescent of light appears. If you look carefully at this crescent, you will see the shape of the rest of the Moon, and the bright crescent part will appear to belong to a larger moon than the dark part. The ancients used to describe this as the new moon with the old moon in its arms.

The reason why the thin bright crescent looks part of a larger circle than the dark part is very simple. If you look at an electric glow-lamp while it is not shining, you can scarcely see the very fine metal wire or thread which is fixed inside the little globe. But whenever the electricity is turned on the little wire appears to be of a very substantial thickness. Of course it has not really become as thick as it looks. But when its bright image falls on the sensitive part of your eye, the sensation spreads and gives you the impression that

the red-hot wire is very much bigger than it is really. When you look at the thin bright crescent which appears at the time of new moon, the crescent appears larger for the very same reason.

How long must you wait to see the next phase of the Moon ? Looking at the drawings on page 81, you will notice that the next phase is the crescent. You will not have to wait many evenings ; indeed you had better keep a good look-out each evening, as sometimes there will be clouds about and you will not be able to see the Moon at all.

If you count the different shapes or phases shown in the drawing on page 81, you will see that there are eight different shapes. You can easily calculate for yourself about how much time will elapse between each phase. You will remember, from our little experiment with the lamp and the orange, that the different shapes appear as the Moon travels around the Earth, and you know that it appears to take the Moon about twenty-nine days to get round the Earth. Therefore the Moon must go through all its eight phases in about twenty-nine days, which means that only about three and a half days

will elapse between the appearance of one shape and the next.

We shall hope for clear weather so that you may see all the changes as they occur. The changes are very gradual, for the bright side of the Moon comes just a little more into view each evening. By the way, the ancients used to think that the Moon had one side which gave out light and that the other side was always black, and they accounted for the different shapes by the Moon turning round and showing us sometimes the bright side, at other times half of the bright side and half of the dark side, and at other times only the dark side.

After you have watched the Moon go through all its phases, you might be inclined to say that the Moon does not turn round at all. For if you watch the eyes and mouth of the Moon's face you will see that no matter what phase the Moon is in the face is always turned towards us. The Moon does turn the same face to us at all times. Then you say that it cannot be turning round, but it does, and yet no man has ever seen the other side of the Moon. I remember that this was a puzzle to me when I was about your age. Even when I read that the reason

for the Moon always turning the same face towards the Earth, was that the Moon turned round in exactly the same time as it took to journey around the Earth, the subject was not clear to me. It became quite simple, however, when I made a practical experiment.

Suppose we make the experiment. You will represent the Earth, and a younger brother or sister, or some other little friend will represent the Moon. The Earth takes up its position in the middle of the room, and the Moon is to travel round it.

If your little friend turns round where he is, you see his face, then one side of his face, the back of his head, and then the other side of his face. How is he to keep turning round and yet show you his face all the time? Perhaps you say that it is because you will have to keep turning round too to represent the Earth's behaviour. But that will make no difference. If you both keep turning you will see more than your friend's full face. You may as well remain steady so that you can keep your eyes on your friend's face as he moves round the room; you can turn round slowly as he moves from place to place, but remember

that your turning round has no part in the explanation.

How is your little friend to turn right round and yet keep his face towards you all the time ? If your friend is to turn right round, he must face each of the four walls in succession. First of all he must look at the wall in which the fireplace is situated. Then he turns to face the windows, then the wall with the door in it, and then the wall with, say, the large portrait of his grandfather hanging on it. You agree with me that it is impossible for your little friend to face each of these four walls in succession unless he turns round completely.

Now I wish your little friend to walk right round you, keeping his face towards you all the time. When he sets off on this journey he happens to be facing the wall with the fireplace. Shuffling along sideways, so that he can keep his face to you, he is soon facing the windows, then he faces the door, and the portrait, and at last he is again facing the fireplace. He has kept his face to you all the time, he has travelled right round you, and he has faced each of the four walls, so we know that he has turned

himself right round. That is just the way the Moon behaves to the Earth.

You will notice that your little friend only turned once round during his complete journey around you. That is what the Moon does. Had your little friend completed his turning round before he had finished his journey around you, then you would have succeeded in seeing the side of his face, and if he had turned round much quicker than he was journeying around you, you would have seen the back of his head also. But he took care that when he was half way on his journey he had only completed one half-turn, and was facing the wall directly opposite the one which he was facing at the beginning. When he had completed his second half-turn, he had completed also his journey, and was exactly where he was at the outset.

And so you see that the solution of the puzzle is that the Moon, like your little friend, takes just the same time to turn round once as it takes to get around its race-course which circles the Earth. And now you can see why I said that if we had remained at the Moon for a whole day we should have had to stay there for a whole month. The Moon's

day and its month occupy exactly the same time.

You know that the Earth journeys around the Sun, just as the Moon journeys around the Earth. And you know that the Earth turns round three hundred and sixty-five times during its journey around the Sun. You know that each complete turn of the Earth, producing light and dark, means one day, and that we divide this day into twenty-four hours. But one complete turn of the Moon takes about seven hundred of these same hours, which is equal to about twenty-nine days, and this we call one *month*. Of course if we lived on the Moon we should call it one *day*, because, while we could see the Earth all the time, we could not see the Sun all the time. There would be sunrise, followed by a very long forenoon and afternoon, sunset and then a very long night; there being seven hundred hours between one sunrise and the next, a day of seven hundred hours.

CHAPTER VI

HOW DOES THE MOON STICK UP IN THE SKY?

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HOW DOES THE MOON STICK UP IN THE SKY?

DID you ever ask yourself how it is that the Moon manages to stick up in empty space? I have asked several young people, and I have received quite a variety of answers. One little girl told me that the sky held the Moon up, but when I asked her how the sky managed to hold it up, she asked me if the sky had sort of hands. Of course you can guess from that answer that she was very much younger than you; she had just reached the very interesting age of six years.

But a very clever girl who was more than twice the age of this little friend said that the sky held the Moon up "by some magnetic influence." Now you and I know that the sky is just empty space, so it cannot be the sky that holds up the Moon.

On another occasion I put this question to a boy of fourteen years of age and he said it was because the Moon was cold. But I failed to

see how the coldness could have anything to do with it, unless he imagined the Moon to be frozen into a solid sky.

A girl of eleven years told me that the Moon stuck up in the sky because it was so high above the air, and that the air drew all things towards the Earth, and that this force is called Gravity. I told her that the force of gravity did not act by means of the air, and when I reminded her that the force of gravity between the Earth and the Moon would tend to pull them to one another, she lost confidence in her answer. I suggested that the Earth, being so very much larger than the Moon, ought to pull the Moon down, and she quite agreed that the most natural thing would be for the Moon to fall down upon the Earth. That is really what would happen if the force of gravity was the only force at work. Fortunately for us that is not the case.

I asked one very intelligent girl who had finished with school, and she thought that the reason why the Moon kept up in space was because the atmosphere was much thicker up there. It is quite evident that she had not been with us on our trip to the Moon.

I asked a friend to put this question to his little girl of nine years of age, and tell me what she thought about the Moon. His little girl happened to know that I was a writer of books, and when her father said that I wished him to ask her how it was that the Moon managed to stick up in space, she said : " Fancy Mr Gibson not knowing that ! " She thought that I was in a difficulty and was anxious that she should help me out.

I asked quite a lot of boys and girls this question about the Moon, but none of them could tell me. I have put the question to you in the title of this chapter, and I am going to suppose that you say you " give it up," and you straightway ask me for the answer.

But I ask you another question. How do you manage to stick up on your bicycle ? You have to keep travelling along. If you ride a bicycle, you probably had some experience of this fact when you were learning how to keep up. Unless you kept travelling along, down you came to the ground. And so would the Moon ; if it stopped moving along it would certainly fall down upon the Earth.

You know how beautifully an aeroplane can

keep up in the air. It must keep on the move also, or down it comes with a terrible crash. Of course an airship or a balloon can rest in the air, because they are lighter than the air, and therefore float in the air like a fish in water, but if the gas escapes from these balloons, down they come to Earth. For the completion of the answer about the Moon, let us make a very simple experiment.

Tie a piece of string to a stone, or, better still, get some grown-up person to do the tying for you, so that there may be no chance of the stone slipping out, as I wish you to swing the stone round and round you. To save any risk of getting me into trouble, I should prefer that you make the experiment only in imagination. It is quite easy, with a little practice, to keep the stone travelling at a steady pace around your head, but if you slacken the pace considerably, down comes the stone to the ground.

I wish you to think of this experiment, and to picture yourself as the Earth, and the stone as the Moon. The Moon sticks up in space in the same way as the stone keeps up off the ground. But you say that the Moon is not

attached to the Earth by a string. That would be like trying to chain an elephant up by means of a thread from a spider's web. We cannot imagine the Moon attached to the Earth by any sort of chain. Nevertheless the Moon is attached to the Earth. By what? Not by anything that we can see. Not by any material thing, but by the invisible æther of space. But what is this mysterious æther of space? I am not surprised that you think it mysterious. It is very mysterious to those of us who have been on this planet much longer than you have. But what is it? I should tell you most willingly if I knew what it is, but I have no idea. If I knew any man who could tell me what the æther is, I would not rest until I heard about it. But no one has any idea.

We know that the æther of space, however, is not any ordinary thing. We know that it fills all space, even away out beyond the stars. Therefore our Earth must be flying through this great ocean of æther as we travel around the Sun. And yet the æther does not stop us on our journey. You remember how the very flimsy air away above the Earth stopped the meteors as soon as they tried to rush through

it. The æther offers no resistance to our grasp; we cannot handle it. We move about in it as if it did not exist. It is most mysterious.

But we know many things that this mysterious æther does. We know that the light which comes to us from the Sun, and from the stars, and from our electric lamps, and from the incandescent mantles in gas lamps, and every other kind of light, is merely waves in this great ocean of æther. We know that when you are sitting in front of a bright fire, and when you feel the fire sending out heat, it is really waves in the æther which are reaching you from the fire. What makes the waves in the æther? It is the fire, of course. Please don't ask "How?" at present, or we shall never finish this explanation of how the Moon keeps up in the sky! Some day we must have a book in this series that will tell you all about how it is a fire can make waves in the æther.

Another thing that we know about the æther is that when we make very large waves in it we can send wireless telegraph messages. I have told you something about this *wireless telegraphy* in *Our Good Slave Electricity*, but some day I shall tell you more about the æther

waves. These waves are very real although they are quite invisible. But what has all this to do with the Moon?

It is this same æther which binds the Moon to the Earth. If I had merely told you that the Moon is connected to the Earth by the æther, it might have seemed very strange to you. It is still very mysterious, but you are not so surprised about it when you realise that light and heat are carried to us by this same æther.

One boy says that he can imagine waves in the æther bringing us impulses of light and heat, but he does not see how waves could help to hold the Moon to the Earth. Neither do I! If the force of gravity is not waves in the æther, what is it? We think it must be some sort of strain in the æther. All I can do is to make some kind of mental picture that may help you to realise the fact that the æther causes the force of gravity. We call these mental pictures *analogies*.

Picture yourself lifting a heavy stone on the sea-shore. You know that the weight does not really belong to the stone, for you remember our experiences with the book and with our-

selves at the Moon. You feel there is a something invisible which keeps pulling at the stone. I could make a rough imitation of what is happening by fastening an empty box to the Earth by means of a number of very strong rubber bands. When you try to lift this empty box it feels very heavy also; you are causing a strain in the rubber bands, and when you let go your hold of the box the strained bands pull the box down again.

Now we suppose that when you lift a stone from the Earth you cause a strain in the æther between the stone and the Earth, and when you let go your hold of the stone the strained æther pulls the stone down again.

You remember that the Moon was once on the Earth; indeed it was a part of the Earth. And you remember how it was thrown away off by the whirling mass of molten material, which we now call the Earth, and upon which we are fortunate in living. So the Moon is just like a great stone lifted off the Earth, and the natural thing is for the strained æther to pull the Moon back on to the Earth. But if, instead of lifting a stone quietly up, you were to throw it with some energy at a distant object,

the stone might travel along quite a distance if you are a good hand at throwing. But even when our great modern guns fire bullets or shells at the enemy's aeroplanes, the bullets are always pulled down to the Earth again. Why is the Moon not pulled down?

I have suggested that the Moon sticks up in space for the same reason as you can stick up on your bicycle. But you say that the bullet shot at the aeroplane is travelling along and only succeeds in staying up for a little. That is because it only succeeds in keeping on the move for a little. Besides, you will notice that it is when a bullet or a stone begins to fall off in speed that it begins to fall. That is just wherein the Moon differs from the bullet and the stone; the Moon keeps going, for there is nothing in its way to stop it, whereas the bullet and the stone have to force their way through the ocean of air. In its present position the force of the Moon driving along is just balanced by the force of gravity pulling it to the Earth.

If the Moon were nearer to the Earth, the pull of the Earth would be greater, and the Moon would require to travel faster in order to keep up in the sky.

Perhaps you wonder if it would not be possible to shoot something, right away from the Earth, with so much force that it would never come back again! I can tell you how this could be done. I mean I can tell you what you must do, but at the same time I could offer you a prize of anything you wish if you succeed. It does not matter if I have the means of buying what you wish or not, for there is no possibility of you earning the prize.

What you must do is to give the object a speed of six or seven miles per second, which means about four hundred miles per minute. With that rate of travel, the object will defy the Earth's force of gravity.

No doubt you have heard the story about Sir Isaac Newton and the falling apple. We believe the story to be a true one. This is what happened some three hundred years ago.

When Newton was plain Isaac, and was a student at Cambridge, he had to leave his studies and go to his home in the country, because of the Great Plague, which occurred in the year 1665. The disease was so prevalent that all the colleges in Cambridge had to be closed. You may have heard about the terrible

loss of life through this Plague. In London alone there were about sixty thousand people died in a few months.

Newton had often wondered how it was that the Moon remained attached to the Earth. You know how the Moon accompanies the Earth in its ceaseless journey around the Sun. When Newton was at home, during the time of the Plague, he happened to be thinking about the Moon when he noticed an apple fall from a tree. I wonder sometimes if the apple struck Newton when it fell. In any case I think it must have fallen near enough to startle him, for he was so absentminded that he seldom noticed what was going on around him. However that may be, it is a fact that the falling of this apple suggested to Newton that it might be the force of gravity which held the Moon to the Earth.

Newton knew what the pull of gravity would be on the material of the Moon, since he believed he knew how far the Moon was from the Earth, and he knew how fast the Moon was travelling, so he made a calculation to see if the force of gravity could account for the behaviour of the Moon. He found that the pull

of gravity was more than enough to keep the Moon where it is. But many years later Newton heard that a Frenchman had made a more careful measurement of the Earth, and had found it to be larger than the earlier measurements. This meant that the Earth being greater than had been supposed when the distance from the Moon was calculated, that distance had to be increased now. So Newton made a new calculation and found that the force of gravity of the Earth could keep the Moon exactly where it is.

When Newton proved that it was common Gravity that held the Moon circling around the Earth, then the whole of the Creator's plan became clear. The force of gravity exerted by the Sun was sufficient to keep all the planets circling around it. Newton had discovered one of the great plans of the Creator.

CHAPTER VII

WHAT MAKES THE TIDE GO OUT AND COME IN?

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WHEN you have been living at the sea, did you ever wonder what it is that causes the tide to go out and come in ?

Sometimes you may have been disappointed to find that the tide was full out just when you wished to launch a rowing-boat which happened to be lying far up on the beach. What a lot of hard work it meant to pull the boat down to the sea ! How you wished the tide had been full in, and you would have been saved all this trouble.

On other occasions you may have been sorry that the tide was full in when you wished to bathe, the nice sandy parts of that particular shore being reached only at low tide. And the worst of it was that there was no use of your trying to arrange your lunch-hour to suit the tide, for it had a bad habit of changing from day to day.

One day the tide would be full in just after

breakfast-time, but in a few days it would be time for lunch before the tide had come full in. You would soon find that the tide was getting later and later each day. How much later?

One day you might find that the full tide was just half-an-hour later than it had been the previous day, but another day you might have reckoned on it being half-an-hour late, only to find that it was more than an hour late.

All boys and girls who have lived much at the sea must have noticed that the tide comes in and goes out twice in each day of twenty-four hours. If you were to note the times of full and low tides, you would find that it took the sea about six and a quarter hours to go from full tide to low tide, and another six and a quarter hours to come in again. To do this double journey twice in each day it requires about twenty-five hours, hence its lateness each day; it cannot complete its work in the twenty-four hours, so it has to finish a bit of it during the next day, and that makes it later in reaching full tide. That is how the tides behave around the British Isles; but in other parts of the World the two tides are not always equal. But what makes the sea rise and fall in this way?

Probably you have heard that the tides are caused by the Moon. This is no new discovery. The people who lived long before the time of Christ knew that the Moon caused the tides, but how the Moon managed to do this they could not tell. No one had any idea of the cause until Sir Isaac Newton discovered the action of the force of gravity between the Earth and the Moon.

You know that not only does the Earth attract the Moon, but the Moon also attracts the Earth. Neither succeeds in drawing the other any closer to it, because of their steady motion in their orbits, or what we called their race-courses. But the waters of the oceans do respond to the attraction of the Moon, and would rise immediately beneath the Moon if the Earth were not rotating.

Of course if there had been water on the Moon, the oceans of water would have been attracted by the Earth to an even greater extent than our oceans are by that smaller body—the Moon. In our trip to the Moon, however, we saw that although there are dark patches, called seas, here and there on the surface of the Moon, there is really no water.

Now when I ask how the tide goes out and comes in, one boy says that the Moon attracts the water of the oceans, and when the Moon rises and sets, the waters rise and fall. Quite a good answer so far as it goes, but I ask this boy how often the Moon rises and sets in each day of twenty-four hours. He knows that the Moon only rises and sets once each day, and he knows that the rising and setting of the Moon is really produced by the Earth turning round once in each day of twenty-four hours, just as the Sun appears to rise and set for the same reason. The effect, so far as the tides are concerned, is just the same as it would be if the Moon did really go round the Earth each day.

The boy says now that he would expect the tide to take twelve hours to go out and twelve hours to come in again. There ought to be only one full tide and one low tide in each day of twenty-four hours. But he knows that there are really two full and two low tides, and he knows that a single journey out or in takes only about six and a quarter hours. He cannot account for these two full tides each day, so he gives up the problem.

One of the girls says she thinks she knows how there are two full tides per day. She says that the Sun also attracts the oceans, and that the Sun produces the second tide. She is quite correct in saying that the Sun does attract the oceans, but she is wrong entirely in supposing that the Sun produces the second tide; their is no division of labour such as she thinks. Besides, the Sun is so very much farther away than the Moon that the Sun's pull on the oceans, though large, is small compared to that of the Moon.

What does really happen is this. When the Moon causes the oceans to bulge out from the Earth on the side of the Earth facing it, the oceans on the other side farthest away from the Moon also bulge out from the Earth in exactly the same fashion. Therefore when there is full tide at Great Britain, there will be full tide at New Zealand also. Of course you all wish to ask why, but I am going to put you off; you must wait till you are older before you can understand the reason why.

Now I wish you to follow a very simple experiment, which can be made quite conveniently in our imagination. We picture a

party of boys and girls, who are playing one of those old-fashioned ging-a-ring games, in which they dance round in a ring.

We tell the boys and girls that we wish them to pretend that they are the oceans of water surrounding the Earth. They are to keep standing in a ring, but they are to turn face outwards with their backs to the centre of the ring. The reason for standing in this fashion is so that they may watch what goes on outside of the ring. The empty ring will, of course, represent the Earth, with the ring of movable waters on its surface.

I select a good strong girl to represent the Moon, and a small boy to represent the Sun. But you suggest that the Sun ought to be very much bigger than the Moon. That is quite true, but in our experiment the Sun is supposed to be so very far away from the Earth that a little boy will represent it better.

We can put the Sun to one side for a moment till I show the ring of boys and girls what they have to do. The Moon is going to walk around the outside of the ring, and as the boys and girls are facing outwards they can watch her passing round.

The room happens to be a good deal longer than it is broad, so that there are two walls which we distinguish easily as the end walls, and two which are quite apparently the side walls. Although the ring is round, we shall think of it as having four corresponding parts ; two ends and two sides.

When the Moon stands opposite one of the ends, the boys and girls facing the Moon are to take one step forward towards the Moon. At the same time the boys and girls forming the other end of the ring are to take a similar step forward towards the wall which they are facing. When these two ends of the ring go outwards, the two sides have to take one step inwards, otherwise the ring would part company.

We remind the children forming the ring that they are imitating the water of the oceans on the surface of the Earth, and that the tide is now full in at the two ends, and full out at the two sides.

When our girl-moon walks round to one side of the ring, the two sides are attracted forward just as the ends were, and the ends go inwards to allow of this movement. The tide is now full in at the two sides and full out at the ends.

When we began the experiment the ring was alike all round, so that we may picture that normal position, which is neither out nor in, as the waters at half-tide. The children took one step forward from half-tide to full tide, but now that the sides had moved one step backwards to represent low tide, they must move two steps forward from low tide to high tide. In the same way when the ends are at high tide they must take two steps backwards to reach low tide.

We continue our experiment by the girl-moon walking round to the next end of the ring. Her attraction causes it to be high tide at the two ends for the second time, and, of course, low tide at the two sides. Her next move to the side causes a second high tide at the sides, and so on. You see from this simple experiment how it is that all parts of the oceans rise and fall twice each day.

Now we are ready for the little boy to join in the game. You will remember that I have chosen a small boy to represent the Sun, so that the boys and girls in the ring will remember that he cannot attract them nearly so well as the big girl representing the Moon.

The Sun rises and sets each day, it appears to circle round the Earth, but you know that it is really the Earth which turns round. The little boy who is to imitate the Sun must walk round the ring just as the girl-moon did. If he were to walk round by himself the result would be a rise and fall of tide similar to that produced by the Moon, but a much smaller movement. There would be only a slight advance at the ends and a slight inward movement of the sides, when the Sun was opposite either of the ends. And when the Sun was opposite one of the sides there would be a small advance at the sides and a slight inward movement of the ends. Now we wish to see the result of the Moon and the Sun both acting on the waters of the ocean. How are we to place the boy and girl ?

If you think of the experiment which we made with the lamp and the orange, you will have no difficulty. You remember that the orange represented the Moon and the lamp represented the Sun, and you will remember that during part of the Moon's monthly journey round the Earth it was on the same side of the Earth as the Sun was, while at another time it was at the opposite side. Therefore sometimes

the girl-moon and the boy-sun must walk round together: that will represent what happens each day at one part of the month. Then they must walk round facing opposite sides, and so on. Let us see what effect these different arrangements have on the ring of waters.

First of all we shall suppose that the Sun and Moon are on the same side of the Earth; the boy and girl walk round together. When they are opposite one end of the ring, the girl-moon attracts the ends to move outwards as before, but the boy-sun also attracts them a little, so that they must move just a little farther forward. The sides will, of course, move a little farther in, for the same reason. In the real oceans this means that when the Sun and Moon are acting together the high tide will be higher, and the low tide will be lower, than is the usual.

These extra high tides are called "spring tides," but as they take place every month of the year it is quite evident that they have no special connection with the season of spring. They will occur twice every month. Why? Let us see what our experiment with the boys and girls has to say in the matter.

Suppose we place the boy-sun at the end of

the ring directly opposite to the girl-moon, the result will be just the same as when the boy and girl were both at one end. They will both be acting on the two ends, causing a second spring tide during the same revolution of the Moon, or, in other words, during the same month.

During another part of the month the Moon will be acting on one of the ends while the Sun is acting on one of the sides. We place the girl and boy to represent these positions, and we watch the result. While the Moon is attracting the ends out and forcing the sides inwards, the Sun is doing just the reverse. The children at the sides of the ring are pulled backwards or inwards by the girl-moon's action on the ends, but the same boys and girls are pulled forward by the attraction of the boy-sun who is acting directly on the sides. Of course the Moon's forcing of the sides to go inwards is considerably greater than the Sun's attraction, so there is still a low tide, but not so low as usual.

If we look at what is happening to the children forming the ends of the ring, we find that the girl-moon is attracting them forward, while the boy-sun, by acting on the sides, is tending to

pull the ends inwards. This prevents the Moon raising the tide as high as usual. We call these "neap tides," and these inferior tides will, of course, occur twice in each month, just as the spring tides do.

During your next holidays at the coast, if you watch the behaviour of the tides you will see that on two occasions during the month the tide comes up higher and goes out farther than the average tide. You will remember that during such times the Sun and Moon are acting together.

On other two occasions during the month you will find the tide taking a lazy turn and failing to rise as high as usual. You will know that the Sun and the Moon are opposing each other, as was represented by the girl being at one end, and the boy at one side, of the ring.

One boy, who has lived a great deal at the sea, and who has become quite familiar with these special tides, says that he used to think that it was the full moon which caused the extra full or spring tide. He used to think that a full moon could attract the waters better than a half-moon. But later on he noticed that the spring tide occurred also when it was

new moon, at which time he could scarcely see the dark moon at all. Then it occurred to him that the appearance of the Moon could have no effect on the waters, for the whole of the Moon was always there, although only a part of it might be seen. He had often meant to ask someone about this subject, but now he sees that the spring tides are produced by the Sun and Moon acting together, and that to pull together they must be opposite to one another, as at full moon, or they must be both on the same side of the Earth, as at new moon. And it is now clear to him that the inferior or neap tides occur when the Sun and the Moon are neither opposite nor together, but in the positions represented by the boy being at one end of the ring of children, and the Moon at one of the sides. In these positions the Sun can light only one half of the Moon's face, and so we have half-moon at the same time as we have these inferior tides.

When Julius Cæsar was getting his troops on board his ships to invade Britain, he noticed that the tide was exceptionally high, and he told the people that this was due to the full moon. We know now that he was wrong,

and that the spring tide and the full moon are both due to the positions of the Sun and the Moon; both are caused by the Sun and Moon being on directly opposite sides of the Earth.

CHAPTER VIII

OUR NEAREST NEIGHBOURS IN SPACE

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OUR NEAREST NEIGHBOURS IN SPACE

OUR imaginary trip to the Moon helped us to realise that the Moon is very much nearer to us than the stars are. We found that travelling at the speed of Light it would take only about one second to go from the Earth to the Moon, whereas it would take us years to reach the nearest fixed stars, travelling continuously at the same enormous speed. But there are some neighbours in space very much nearer to us than we are to the fixed stars. Some of these near neighbours could be reached in a few minutes with the aid of our wonderful flying machine; others could be reached in a few hours.

You can see some of these near neighbours when you look up into the sky at night. You would call them stars, but you would notice that some of them are much brighter and bigger looking than the stars.

If you were to make a study of the positions

occupied by these near neighbours from month to month, you would find that they seem to wander among the stars. The ancients noticed this and they called these "the wanderers," and we have a special name for them to-day. We call them *planets*, and this English word is made up from the Greek word which means *wanderer*.

But you must not imagine that these planets wander about in an aimless fashion. I remember being present at a lecture about the planets, many years ago, and the lecturer showed on the lantern screen "the paths of the different planets among the stars." I remember wondering how many of the audience would imagine that the planets really travelled to and fro as shown on these lantern slides, for the lecturer made no remark about these being the *apparent* paths.

When the ancients traced out these very curious paths which the planets seem to follow in space among the stars, they believed that the planets did wander about in that fashion, but when it was realised that the Earth and all these planets were journeying in almost circular paths around the Sun, the apparent wanderings

of the planets were explained; our point of viewing the planets was changing continually.

There are eight planets travelling round and round the Sun, and you and I are being carried through space on the surface of one of these eight planets. Each planet has a name, and you know that the planet upon which we live is called the Earth. There is no fear of collision between any of these planets, as each has a separate race-course quite apart from its neighbour's courses.

We picture the great Sun at the centre of all these race-courses, as shown in the accompanying drawing. We call these great circles the *orbits* of the planets. We have made up this word from a Latin word which means a *wheel-track*. As the word *orbit* is not one to which you have been accustomed, I shall continue to speak of these great paths of the planets as their *race-courses*, allowing the word *orbit* to creep in occasionally. Now we wish to take a look at the drawing which is marked Fig. 7.

You see that the planet Mercury has the smallest course to travel round, and that Venus circles round outside Mercury's orbit, while the Earth comes next, and then the planet Mars.

These are the four innermost of the eight race-courses. Why does the drawing not show the whole eight at one time? Because the next race-course is so much farther out that it could not be drawn on this size of page. The

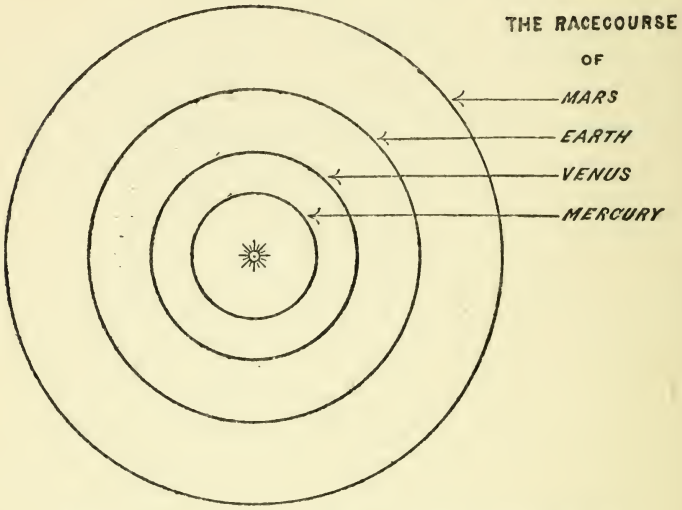

FIG. 7.—The race-courses of the four planets nearest the Sun

only way in which I can show you the whole eight race-courses at one time is to draw them all on a very much smaller scale. You will understand that in the drawing (Fig. 8) the four innermost race-courses are represented by the tiny ring at the centre; that is the size of Mars' orbit in proportion to the others.

Suppose we set out on another trip in our wonderful flying machine, in order to have a look at each of these eight planets. We shall take a run down to the neighbourhood of the Sun, and then merely cross over each of the race-courses in turn, going at the speed of Light

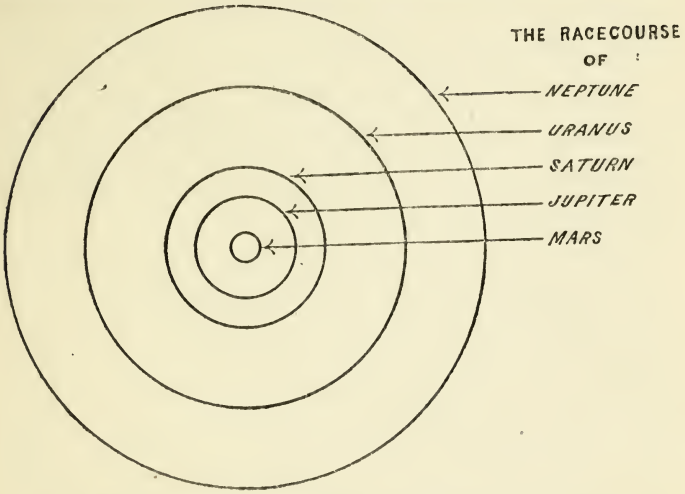

FIG. 8.—The race-courses of the four planets farthest from the Sun

all the time, so that we may form some opinion of their different distances from the Sun. Then on our homeward run we can take time to have a look at each of the planets.

After getting clear of the ocean of air which surrounds the Earth, it will take us only a few minutes to get as near the Sun as we care to go.

Turning our back upon the Sun, we see Mercury against the black sky, but we are past it and near to the race-course of Venus in less than three minutes.

We have a passing glimpse of Venus in the distance, and in two minutes we reach the race-course, or orbit, of our own planet, the Earth. Fortunately we are quite clear of this planet, as we do not wish to pass through its ocean of air, or we should be forced to reduce our speed, and then we could not compare the distances between the race-courses.

When I announce that in other five minutes we shall cross the race-course of Mars, every boy and girl is anxious to have a good look at this planet. They wish to see if they can detect any signs of human beings on its surface. But Mars does not happen to be anywhere near the part of the race-course over which we cross. We see Mars some distance off, and although it looks very much bigger than it does from the Earth, we cannot see any details of its surface.

There is some disappointment that we have to fly on our journey without stopping, but I promise that on our return journey we shall hunt down each planet, and have a good look

at all the detail which is visible. If we were to do that now, we should have no idea of the positions of the different race-courses.

It has taken us rather less than a quarter of an hour to reach the race-course of Mars, starting from the neighbourhood of the Sun, and we have passed the race-courses of Mercury, Venus, and the Earth on our way to Mars. Fig. 7, on page 128, shows a map of our journey so far. A very few minutes brought us from one race-course to its neighbour, but now we shall have to travel full speed ahead for half-an-hour before we reach the next race-course, along which the planet of Jupiter travels.

I feel a little bit worried about this crossing from Mars to Jupiter, but I need not worry you boys and girls with it; you may speak to one another, but do not speak to me, on this part of the journey; I shall tell you all about it later on.

When we reach the race-course of Jupiter without any mishap, the boys and girls are all greatly surprised at the enormous size of Jupiter, but we shall stop and have a look at this giant planet on our return.

To reach the next race-course, the one belong-

ing to Saturn, will take us another half-hour, but it is a still longer journey from that race-course to the neighbouring one, belonging to Uranus. This crossing takes us one and a quarter hours, and the remainder of our journey out to the race-course of Neptune takes us another one and a half hours.

When I intimate that this is the end of our outward journey, one of the boys is very anxious that we should continue our journey outwards and discover if there are any more planets farther out in space. This would be of special interest, as the astronomers on the Earth cannot discover if there are any more planets farther out than Neptune. But, as we are already nearly three thousand million miles from the Earth, I think we ought to be content.

Another reason why I am unwilling to go farther is that the distances between the neighbouring planets has gone on increasing the farther out we have come. It took us only a few minutes from the Earth to Mars, but it has taken us an hour and a half from Uranus to Neptune. You must remember also that although we have taken only about four hours to travel from the Sun to Neptune, it will take

us a very great deal longer to go home by the zigzag path necessary to bring us close to each planet. And we are not going to be content to fly past the planets at the rate of eleven million miles per minute.

First of all we pay Neptune a visit, and one boy proposes that we should anchor our flying machine to this planet, and let it pull us once round its race-course. I shake my head quite decidedly, for, in the first place, we should not find Neptune a very good anchorage. It seems to be made of great clouds of heavy vapour, and it is quite apparent that Neptune is very hot, for its clouds are continually on the move, just as though they were boiling.

Neptune's clouds are quite different from the clouds which float in the air around our Earth. Our clouds are masses of water vapour raised by the heat of the Sun, but Neptune is far too distant from the Sun to be affected in that way. Neptune's clouds are made of the materials of which the planet itself is formed, and it is the intense heat of the planet which throws up these clouds and keeps them in constant motion.

You will agree with me that even if there

should happen to be a solid centre in this great planet, it would not make a suitable anchorage.

One girl suggests that Neptune is much liker the Sun than the Earth, but it is really not like either of them. It is not a compact, solid ball like the Earth, nor is it a red-hot mass of glowing vapour like the Sun. It is between these two conditions, and is at a stage through which we believe our Earth passed millions and millions of years ago, when the Earth was, as we read in the first chapter of Genesis, "without form and void."

There is no doubt that both Neptune and the Earth were once so hot that they sent out light as the Sun does to-day. Neptune looks as though it were just past the red-hot stage, and you know that our Earth is in a condition which you would describe as *cold.*

But we were talking about letting Neptune pull us round the Sun. The boy who made this proposal cannot find anyone willing to fall in with it; all say that they are not anxious to stay away out in space here for a whole year. They are much more unwilling when I explain that Neptune's "year," or complete journey around the Sun, is a very great deal longer than

our year. It takes Neptune about one hundred and sixty-five of our years to get once round its great race-course; we should all be dead before we had got one half-way round Neptune's course.

Not only is Neptune's race-course a very great deal longer than the race-course of the Earth, but Neptune is travelling at a very much slower rate than the Earth. One girl says that Neptune is an old slow-coach, but if this girl could travel as fast as Neptune does she could win all the prizes given on the Earth for tests of speed. She could enter with confidence in a race against a motor cyclist; she could overtake, and run past, an express train, and she could travel faster than the fastest aeroplane. Indeed she could go as far in one minute as an aeroplane could go in one hour, for the speed of Neptune is about two hundred miles per minute, or twelve thousand miles per hour. No one can call Neptune a slow-coach.

Now we shall make our way back to Uranus. We have become accustomed to the jet-black sky, but one boy asks why it is so dark up here. It is certainly lighter than the best moonlight night which we have experienced on the Earth,

but it is very far short of daylight on the Earth. I answer this boy, in real Scotch fashion, by asking him another question. Where is the Sun ? Some point to one tiny speck of light and some to another, but which of these two objects is the Sun they cannot decide. They are surprised when I tell them that neither of these is the Sun ; these are the planets Saturn and Jupiter. That small star away in the distance is the Sun. It looks very much as the planets appear from the Earth ; indeed from here you might easily mistake the Sun for Venus. This reminds us how very far distant we are from the Sun and from the Earth.

It is a good thing that we have not to travel back at our second speed of one hundred miles per hour, for it would take us three thousand years to reach the Earth. Going at our top speed, the speed of Light, we could be home in a few hours, but we wish to spend a little time at each planet on our way. We set off now for Uranus.

We were talking, a little while ago, about the speed of Neptune, and we saw that this farthest-out planet was not such a slow-coach

as one of the girls tried to make out. But it is hardly fair to compare the speed of a planet with that of railway trains or aeroplanes ; these have so much air-resistance and friction to overcome, whereas the planets have none. It will be more reasonable to inquire how Neptune will fare in a race with one of the other planets, say with our own Earth.

Suppose we time the two planets over a distance of five thousand miles ! We find that the Earth reaches the end of this measured distance in five minutes, whereas Neptune does not reach the end of the same course for half-an-hour. The Earth is travelling through space six times faster than Neptune.

We are not going to trouble about the speeds of all the planets, but it is of interest to notice that the nearer a planet's course is to the Sun the faster does that planet travel.

We are coming near to Uranus, and it seems strange to us that the planet has more than one moon circling around it. As Uranus has practically the same appearance as Neptune, we need hardly pull up here, but rather set our course to overtake Saturn.

As we fly away from Uranus, we try to count

how many moons are circling around that planet. We manage to count four moons, and indeed there may be more.

We ought to have counted the moons going round Neptune, but all we can be sure of now is that there was one moon at least. Probably we should have found more if we had been on the look-out for them. We shall pay more attention to the number of moons attached to the other planets.

We are well on our way to Saturn, and we are looking forward to an examination of the great ring which that planet carries around its waist.

CHAPTER IX

A CURIOUS PLANET AND A GIANT ONE

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WE are going to make no mistake about the number of moons possessed by the planet Saturn, so we begin to count them as soon as we can see them distinctly. One, two, three, four, five, six, seven, eight, nine, ten ! Fancy a planet having ten moons !

One boy suggests that there may be a collision some day between two of Saturn's moons, but I shake my head. Why ? One girl guesses that they are all travelling at exactly the same speed, so that no one can overtake another. But that is not the case ; some are travelling very much faster than others. Besides, one of the moons is travelling in the opposite direction to all the others, which is an unusual thing, although Uranus and Neptune have each a moon going contrariwise also.

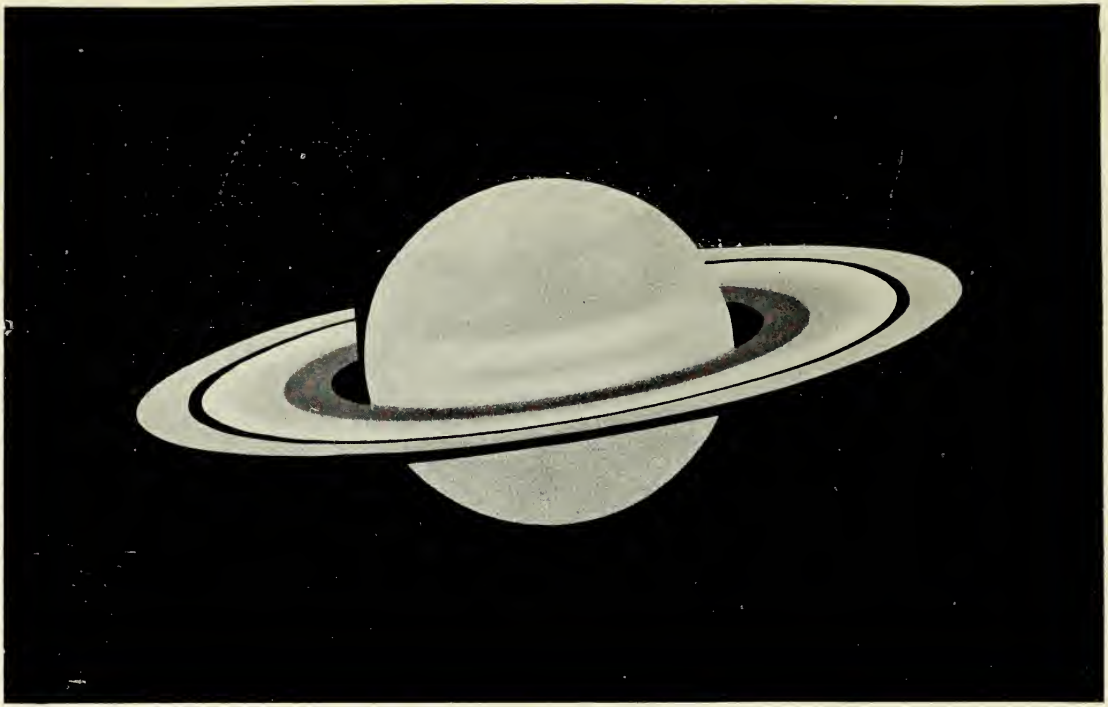
The reason why there is no fear of collision between the ten moons of Saturn, is that each moon has a separate race-course of its own, just

as the planets have. Indeed Saturn and its ten moons are not unlike the Sun and its planets, only Saturn does not send out light as the Sun does. Saturn is hot like Neptune and Uranus, and it sends some heat to its moons, but it is no longer red-hot.

We are near enough now to see Saturn's great ring very clearly. You will see a picture of this wonderful planet on the page facing this.

When we pull up to have a good look at Saturn, we stay at a very respectable distance, for the planet is so large that we could not get a proper view of its ring otherwise. We see that the huge ring is made up really of three separate rings, one within another. The two outermost rings are bright, and are separated from each other by what looks to us like a narrow, dark space. The innermost ring is not so bright as the other two, and we notice that this ring is not very solid, for we can see the body of the planet through it. There is a clear space separating this ring from the planet, so that the three rings really float in space around the planet.

Taking a nearer view of the rings, and looking right down upon them, they form a broad



A Picture of Saturn

This drawing of the p'anet Saturn shows you what it looks like through a large telescope. Without a telescope it appears to us to be merely a point of light.

band, which seems to be as wide as one half of the great planet itself, which means that the band is about forty thousand miles in breadth. A regiment of planets the size of our Earth could stand five abreast on the width of this great band. If you cannot picture such a regiment, think of the four planets, Mercury, Venus, the Earth, and Mars, all standing side by side on the width of Saturn's rings! They would occupy only about one half of the available room. Of course I am speaking all the time of the width or breadth of the band formed by the three rings.

We can see now quite clearly that the rings are not stuck on to the planet; there is quite a large, empty space between, and this space must measure thousands of miles.

From our present position we cannot see how thick the band of rings is, but one thing we do see is that the rings are not solid. They seem to be made up of millions and millions of separate particles. The particles do not look bigger than grains of dust, but they may be as large as pebbles.

The rings do not look so nice and regular when you get near them, the particles seem even to

surge about as they go round in this never-ending dance. Their perpetual motion in this fixed race-course is a grand demonstration of the force of gravity; the particles are really attached to the great planet by the mysterious ether of space, just as our Moon is attached to the Earth.

One boy says that his grandfather told him that there were people living on Saturn. The astronomers of fifty years ago did believe that, and this boy's grandfather probably read some of the books in which these astronomers declared that there were people living on Saturn, but he has not read more recent books, or he would have found that astronomers do not believe this now.

If astronomers had believed still that there were people living on Saturn, we could have taken back word to the astronomers on the Earth that they were quite mistaken, for we can see that Saturn is in very much the same turbulent condition in which we found Neptune and Uranus.

See how the hot clouds of vapour produce the appearance of dark and bright belts on the planets! These belts keep changing from time

to time. If Saturn is solid at all, it must be only in the centre. The heat is intense, but not sufficient to make the planet red-hot; it only shines by reflecting the sunlight.

As we leave the neighbourhood of Saturn, we have to alter our course again in order to reach the giant planet Jupiter. But where is the Earth?

We cannot see the Earth anywhere. I try to pick it out, but it is too near the Sun to see it, it reflects so little light compared to the light of the Sun, although it too appears quite a small object from this distance.

One girl asks what will happen if we cannot find our way back to the Earth. I remind her that we have the different planets as stepping-stones, and that in any case we could calculate how long it would take us to travel from Saturn to the Earth. We should find that it would take us a little more than an hour, so if we were to steer straight for the Sun and then pull up in an hour's time we should be somewhere near the invisible race-course round which the Earth is travelling. However, we can see the giant Jupiter, and that is our next object of interest.

Looking back at Saturn, one boy declares

that its great rings have shrunk to the thickness of an ordinary wedding ring. As we proceed a little farther on our journey one of the girls says that the rings are no thicker than a sheet of notepaper; she can scarcely see them at all. But we must remember that we are already a considerable distance from Saturn, and we are looking at the rings edgewise.

When I ask the boys and girls to guess how thick the rings are really, some say so many inches, while others say so many yards. They are a little surprised when I guess fifty miles, but I am really not guessing; I know that astronomers on the Earth have been able to measure the thickness of the rings and that they find it to be about fifty miles.

This very curious planet, Saturn, looks like a mere point of light when we view it from the Earth, unless we look through a telescope and then we see its rings. One boy says that his father has often pointed out Saturn to him, but he has never shown him Neptune or Uranus. The fact is that you cannot see Neptune without a telescope, and Uranus is practically invisible also. In certain years Uranus might be seen very faintly without a telescope, but

only by those who know where and when to look.

The best part of half-an-hour has passed since we left Saturn, and we are so near Jupiter that we can see only a small part of it at a time. Its surface is very much like that of Saturn; it is enveloped in hot clouds of heavy vapour.

While we watch the great markings on its surface change, we realise that the inside of the great planet must be very hot still. We can see that it is no longer red-hot, although astronomers of not so very long ago did believe that Jupiter was still shining by its own light.

It is difficult to realise what a giant Jupiter really is; even when I tell you that if all the other planets, including the Earth, were rolled together into one great ball, it would not be so large as Jupiter. You remember that we found it would take us about ten days to fly once round the Earth in a flying machine going at the constant speed of one hundred miles per hour. A similar journey once round Jupiter would take us more than a hundred days.

As we fly onwards we count Jupiter's moons. We manage to count nine moons, although some of these are not very large. One is about the

size of our own Moon, and three are still larger, but the other four are very much smaller. One of the moons is travelling in the opposite direction to the others, so you see it is quite the fashion for these great planets to have a retrograde moon; you remember that Uranus and Saturn each have one travelling in what you might call this backward fashion.

It is worth while noting that Jupiter's nine moons together do not reflect nearly as much light as our one Moon does, but you must remember that our Moon is very much nearer to the Sun.

It will take us about half-an-hour to cross over to the race-course of Mars, but we have had longer journeys from Neptune to Uranus, from Uranus to Saturn, and from Saturn to Jupiter. But you will remember that I did not like this journey between Mars and Jupiter on the outward run, and I may tell you I have the same uneasy feeling about recrossing this space, but if none of you bother me during this run I shall explain matters when we reach Mars.

When we have got safely over this crossing, I ask the boys and girls if they can guess why I have been more worried about this particular

space between Mars and Jupiter than I have been with even the more distant parts of the journey.

One boy thinks he can explain. Remembering the alarming adventure on our journey from the Earth to the Moon, he suggests that there are meteors flying about in this space between Mars and Jupiter; but he is wrong.

Another boy suggests that Mars has a great atmosphere around it, and that I was afraid our flying machine might enter it suddenly, and cause us to become red-hot vapour, as did the meteor. But this boy is wrong also.

Another boy suggests that there is some great dark planet in this space which cannot be seen, as it does not reflect the Sun's light, and that I fear a collision. He is wrong also, but his idea is much nearer the truth. There is not one large, dark planet, but there are seven hundred or more very small planets. These are all flying around the Sun in this space between Jupiter and Mars. No wonder I was a little anxious about this crossing.

About how big are those small planets? I knew that question was sure to come, and I believe you might quarrel with me for having

called some of them "small." One of them measures between four and five hundred miles across; we say that its diameter is about five hundred miles. But even that is really small compared to Mars, which measures four thousand miles in diameter. We might even describe the five-hundred-mile planet as "tiny" compared to the giant Jupiter, whose diameter measures eighty-five thousand miles.

These small planets have been named *asteroids* or *planetoids*. Only four of them can boast of being more than a hundred miles in diameter. Few of the seven hundred asteroids exceed twenty-five miles, while some do not appear to be more than ten miles in diameter, but we have no exact measurements of the smaller ones.

When you are down on the Earth you cannot see these asteroids. There is one of the four large ones which might be seen without a telescope under very favourable conditions, but even it is very faint and would require a practised eye to pick it out. There are many of the asteroids which cannot be seen even with the best telescopes. How then do we know of their existence?

I was quite prepared for this question, and I

could see that some of the boys and girls thought I was romancing a little, for how could we possibly know of asteroids that no astronomer has ever seen? We know of these invisible asteroids because they have appeared in our photographs of the sky. The asteroids are easily distinguished from the fixed stars appearing in the photographs, for the asteroid, being on the move, leaves a trail on the photographic plate; just what you would describe as a streak of light. We must remember to have a talk about the photographing of the stars when we get back to the Earth.

One boy asks how it comes about that there are hundreds of small planets in this space between Mars and Jupiter. He wonders if there was at one time some great planet in this space, and somehow or other it has gone to pieces. Another boy suggests that there may have been two planets, and that they collided with each other, and that the asteroids are the fragments.

These suggestions are all quite reasonable. The idea of the asteroids being fragments of an exploded planet was accepted by astronomers at one time, but reasons have been advanced

to show that this is not likely to have been the case. Other astronomers have suggested that certain influences have prevented a planet forming in this space, and that these asteroids are made of the material which, but for these supposed influences, would have gone to make another large planet. You see that we are not quite sure how the asteroids came to be there.

You will notice that while we have been discussing these asteroids all the suggestions have been made by boys; the girls have been looking out at Mars in the hope of finding some signs of human beings on its surface.

CHAPTER X

ARE THERE PEOPLE LIVING ON MARS?

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WE have heard so much about the Martians, the people who live on Mars, that we are very curious to see them, if there are such people.

We have seen that no one could possibly live on any of the great planets which we have visited. Neptune, Uranus, Saturn, and Jupiter are not the cool, solid planets which might make comfortable homes for living beings. These four outermost planets are all intensely hot, and their surfaces at anyrate are composed of heavy clouds of heated vapour. But Mars is quite different.

We can see that Mars is a solid planet. Indeed, from the clear view we have of it, we should guess that there is no air around it, and we cannot see any clouds. That great dark patch of its surface, shaped something like a huge balloon, has a Latin name which means the *Hour-glass Sea*. It has been named

also the *Kaiser Sea*, not after the German Emperor, but after a Dutch astronomer whose name was Frederick Kaiser.

Are there many seas on Mars? There are none. The earlier astronomers made the same mistake about Mars as they did about the Moon. Is there any water on Mars?

Looking at the great snow-caps at the poles, we should say that there must be water, for these snows melt in summer-time and appear again in winter. However, some people suggest that this snow is not really frozen water, but is frozen carbonic acid gas. So far as we can see, there are no traces of water over the surface of Mars, and we certainly see no signs of human beings. This is a great disappointment to those young people who had hoped to see the Martians.

We must not forget to count how many moons there are circling around Mars. One girl says that there are none, for she has read Tennyson's beautiful poem in which he speaks of "Moonless Mars." But Tennyson was wrong, although we have to blame the astronomers and not the poet. At that time the astronomers said that Mars had no moons, but

later on it was discovered that this had been a mistake.

We have difficulty in picking out any moons around Mars, but at last we see two very small moons circling close to the planet. The one which is making the wider circle does not look more than ten miles in diameter, while the one closer to the planet may have a diameter of about forty miles. But we cannot see them very clearly, for they reflect so little light. No wonder that the astronomers away down on the Earth had difficulty in finding these moons with their telescopes.

The larger of the two moons, which is nearest to Mars, makes a complete journey around the planet in seven and a half hours. If there had been people on Mars they would have seen this moon cross their sky three times every day, for their day is about twenty-five hours. The smaller moon, which is farther out, takes one and a quarter days to get once round Mars.

We look forward again to see the Earth, but it still looks just like a star, only it is much brighter than it was a little while ago. Five minutes will take us to the Earth's race-course, but, as the Earth happens to be away round

near the other side of its great course, it will take us fully a quarter of an hour to reach it.

On this journey towards the Earth's race-course we might have caught sight of a very small planet called *Eros*. You never heard of it before? It is there all the same, and is constantly circling around the Sun in a race-course of its own between the race-courses of Mars and the Earth. But none of us noticed Eros; it may be that we were too busy discussing the possibility of there being people on Mars, or it may be that Eros did not happen to be near this part of the race-course which we have just crossed. We could not have picked Eros out from any distance, as its diameter only measures about twenty miles. It is just about the size of many of the smaller asteroids.

One boy says that he does not see how it was possible for astronomers to discover Eros, seeing they can never hope to see so small an object at this distance from the Earth. You and I know how they would manage, and I fear the boy who has put this question has not been listening when I was explaining that astronomers had discovered the asteroids by means of photography. You remember how

these moving asteroids left a trail of light on the photographic plates, proclaiming themselves to be "wanderers" (planets) and not fixed stars.

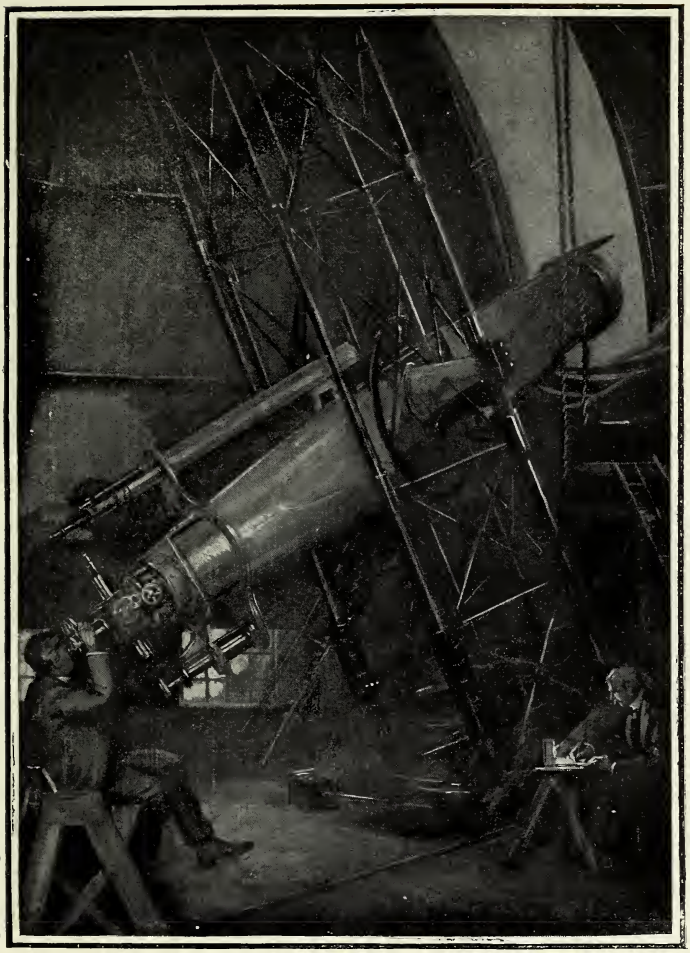
While we have been talking about Eros, we have got fairly near to the Earth, but I wish to steer clear of it, as we have still to visit Venus and Mercury. In two minutes we could cross over to the race-course of Venus, but we have to go off at an angle to catch up on that planet which has passed this part of its race-course some time ago.

A boy and girl are having a discussion as to how people ever got the idea that there were human beings living on Mars, and they apply to me for an explanation. We have seen already that astronomers at one time believed Saturn to be inhabited by people, and at an earlier date it was declared that even the Sun was inhabited. The people were not supposed to live on the hot surface of the Sun, but to dwell on a cool, solid centre with an envelope of warm and shining clouds overhead. And so we need not be surprised that it seemed possible for Mars to be inhabited.

When astronomers came to possess really

good telescopes, they were able to say quite definitely that the planet Mars was solid, and was not composed of vaporised material, as the four outermost planets are. Indeed it became quite certain that Mars had cooled down further than this Earth, though not to the dead state in which we find the Moon.

Mars is older than the Earth; but even if Mars were just the same age, it would be colder, because it is very much smaller. You know that the Moon was once part of the Earth, so that at the moment of parting company they were of the same temperature, but the Moon, being smaller, has lost its heat much quicker than the Earth. In the same way the Earth and Mars were both part of one great glowing Sun in the long, very long ago, so they set out on their own account at something like the same temperature. Mars parted company with the Sun earlier than the Earth did, and so it has had longer to cool down. But, what is of more importance, Mars is just about one half the diameter of the Earth. Better still, if we consider the mass of material in each of these planets, we find that the mass of the Earth is nine times the mass of Mars.



A Great Telescope

This picture shows an astronomer examining the stars through a very large telescope, while another observer is taking notes.

For size, Mars is just about midway between the Earth and the Moon.

You remember that the Moon has no atmosphere to act as a blanket, and so it cannot bottle up any of the Sun's heat. Mars has no atmosphere such as our Earth has. It may be that it has an atmosphere of carbonic acid gas, in which case that would act as a very good blanket. No person or animal could live in carbonic acid gas; it would choke us at once.

Believing that Mars did possess an atmosphere like ours, some astronomers thought they had found proof of the existence of human beings away up on Mars. An Italian astronomer found some markings on the surface of Mars, and they looked to him exactly like great channels; you know what our English Channel is like.

The Italian astronomer described these as channels, the Italian word for *channel* being *canali*. He called them "canali," but unfortunately, when this word was translated into English, the translator used the word "canals" instead of the correct word, "channels." You know that a canal is a waterway made by men for a special purpose, usually for conveying

ships from one sea to another through the land. You have heard of the Suez Canal and the Panama Canal, and possibly there may be some small canal in the neighbourhood in which you live.

But surely the wrong translation of a word would not lead people to believe now that there are artificial waterways on Mars. A misunderstanding such as that could be corrected, but in the interval an American astronomer declared that, with his huge telescope perched on the top of a high mountain, he could see a great number of canals, for which he could not account, unless they were the work of intelligent people.

Other equally eminent astronomers looked for these canals and could not find them. Others, again, did see them, but there are still some doubters who believe them to be what we call optical illusions—deceptions in our powers of seeing.

One girl asks why the American astronomer had his large telescope right up on the top of a high mountain. A boy guesses that it was in order to get as near Mars as possible, but I ask that boy if he thinks he would see the Moon

any better by standing on his tiptoes. He forgets that Mars is millions of miles from the Earth.

The reason why the astronomer took his telescope to the top of a high mountain was to climb out of the great blanket of air as far as he could, as the air, although invisible to us, interferes in some measure with the rays of light reaching his telescope. Indeed the condition of the atmosphere in Great Britain prevents us seeing the so-called canals altogether.

Whatever these "canals" may be, they did not attract our attention as we passed Mars. We are perfectly certain that we did not see anything to suggest that there are human beings on Mars. All the fanciful pictures of the Martians must be fairy tales to us in the future. Mars is much more like the Moon than like the Earth.

Our two last places of call are very near to the Sun, and the light of the Sun is so intense that we cannot look at the Sun even with the special dark glasses which we brought with us.

While approaching Venus, and sheltering our eyes from the glare of the Sun, we see that the planet looks like a crescent moon, but we

steer a course in between the planet and the Sun, whereupon we see Venus as a full moon.

Of course you know that Venus is not a moon, it does not dance attendance to any other planet, but when we see only a crescent of it lighted up it looks very like our own Moon.

We slacken speed for a few minutes to have a look at this side of Venus, as the other side, which is turned away from the Sun, is in darkness. Some of the boys say that they can see Venus turning round, but they cannot see this, as Venus behaves to the Sun exactly as our Moon behaves to the Earth; Venus always turns the same face to the Sun. You would not like to live upon the other side of Venus, from which you could never see the Sun.

If you feel the least bit mystified about Venus always turning the same face to the Sun, and yet turning round once during each journey around the Sun, you must just repeat the experiment explained on page 88. This time, when you stand in the centre of the room, you will be the Sun, and your little friend who walks round you, keeping his face to you, will be Venus.

But the boys still believe they see Venus turning round; they have been watching a

dark patch on it. That dark patch, however, is only the shadow of our flying machine, as you will see when we go nearer to the planet. We are travelling at our slow speed, so we need not fear any accident from entering the atmosphere of Venus.

We are not going to circle around Venus, for that would take us about ten days, Venus being almost the same size as the Earth. Besides, for about five days of the journey we should be in total darkness on the other side of Venus, as she has no moons to reflect any of the Sun's light.

Now you can see that this dark patch is really the shadow of our flying machine; we are cutting off some sunlight. But surely the surface of Venus is like a sea of snow. What we are looking at is not really the surface of the planet, but an envelope of clouds surrounding the planet.

The boys suggest that we should go down through the clouds and see the surface of Venus, but I am not willing to do so. Why? Because I believe that some of the mountain-tops reach the cloudy envelope, and occasionally these may be seen peeping through the clouds; we

do not wish to risk an accident to our flying machine. Besides, this sea of clouds is not at rest; indeed it looks as though the clouds were being blown along by a regular hurricane.

Now we shall make our way over to the last of the planets, the one nearest to the Sun. We cannot say of Mercury "last but not least," for it is by far the least of all the planets; indeed it is just about the size of our own Moon.

We are interested to have a look at Mercury, because when we look up at the sky from the Earth we cannot see Mercury; it keeps so close to the Sun. But even now, in our flying machine, we do not care to take more than a hurried glance, as we are much too near the Sun ourselves. We are really over thirty millions of miles away, but when on the Earth we are about ninety-three millions of miles distant from the Sun.

All that we can see of Mercury is that it has evidently no atmosphere, and that its surface is very much like that of our own Moon.

We are glad to get away from the close neighbourhood of the Sun, for although we have confidence in the heat-resisting materials

and screens with which the builder has fitted up our wonderful flying machine, yet we have recollections of seeing moths dive right into bright flames, not that they had any desire to do so, but by being completely dazed by the light.

We shall feel more comfortable in having a talk about the Sun when we get back to the Earth.

CHAPTER XI

OF WHAT IS THE SUN MADE?

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HAVE you ever wondered of what the Sun is made ? When I put this question to boys or girls they usually answer that it is a ball of fire, but they have no idea of what the fire is made, or how it lasts so long without burning out.

Of course a large bonfire will last a long time, and the Sun is certainly very large ; it occupies a space more than a million times larger than that occupied by the Earth. But even a bonfire as large as the Sun would burn out in about five thousand years.

One boy says that perhaps the Sun *will* burn out in five thousand years, and we shall know nothing about it, as we shall be dead long before that. Five thousand years is a very long time ; less than five thousand years ago old Abraham, Isaac and Jacob lived upon this planet. But we have positive proof that people lived long before five thousand years

ago, so the Sun cannot be burning like a bonfire.

To-day we are digging coal out of the Earth, and we know that this coal is the remains of great forests of fern-trees which grew millions and millions of years ago. These great fern-trees could not have grown without the heat of the Sun, and so we are quite sure that the Sun has been blazing away for millions of years.

One boy points to an electric glow-lamp and suggests that the Sun is like the red-hot filament in the lamp ; there is no air in contact with it, so there cannot be any burning away. It is quite true that there is no air around the Sun, and that therefore it does not burn away. But what keeps it red-hot, or, rather, white-hot ?

Our young friend who proposed the similarity between the white-hot filament of the lamp and the Sun ventures to suggest that it is Electricity which keeps the Sun at such an intense heat. It is the passage of an electric current through the filament of the glow-lamp that keeps it white-hot, but we have an engine and dynamo forcing Electricity through the glow-lamps, and we cannot imagine a giant

electric current being forced through such a huge mass as the Sun. Besides, the energy required to drive the electric current would require to come from without the Sun; the idea is quite unthinkable. How then can the Sun maintain its heat for millions of years?

One girl suggests that the Sun has been created as a great white-hot ball, and that it is cooling down so very gradually that we do not notice any change. It is true that a huge white-hot ball, the size of the Sun, would take a very long time to cool, but it has been calculated that such a cooling down of the Sun could not last three thousand years. So you see that if the Sun were merely a white-hot body cooling down, it would not last so long as it would if it were burning away. We are forced to believe that the Creator has arranged things so that the Sun is able to keep itself at white heat for millions of years.

But the Sun is giving off heat; we know how it is pouring down heat continually upon this planet on which we live, and our planet only receives a very, very small fraction of the heat sent out by the Sun. We could not live without the heat of the Sun; we should be

frozen to death. But if the Sun is giving away heat continuously there must be a loss of something within the Sun. We have seen that none of its material is burnt away: what then can it lose ?

No doubt you have seen a blacksmith at work. You may have seen him hammering a piece of cold iron, and you can easily understand that it will become hot with repeated hammering. The smith could hammer the iron for hours but he could not make it red-hot; it would radiate away so much of the heat between each stroke. A quick-working steam-hammer could make a piece of cold iron red-hot in less than a minute; I have seen it done. This steam-hammer was striking the iron so rapidly that the iron could not get rid of the heat between the strokes. The steam-hammer could go on keeping the iron red-hot all day. But we have to keep supplying the steam-hammer with the necessary energy; we keep stoking the furnace, which boils the water for producing steam to drive the hammer. The hammer expends energy at the cost of burning the coals.

It goes without saying that there are no

steam-hammers in the Sun, but there is something which acts in the same way. For instance, when I let a stone fall from a height it will produce heat when it strikes the pavement; the stone imitates the steam-hammer. It will not make the pavement or itself red-hot, for the same reason as the blacksmith fails to make a piece of cold iron red-hot. But we can prove that when the stone strikes the pavement, there is some heat produced. When a rifle bullet is stopped by a target there is a very much greater amount of heat produced; you can easily feel the heat.

There are particles constantly falling in the Sun. No doubt there are flying meteorites falling into the Sun, but I do not refer to these. The Sun itself is shrinking in size, and the particles forming the outer part of it are falling towards the centre of the Sun. The continuous falling of these particles produces sufficient heat to keep the Sun white-hot.

But one boy says that if the Sun is really shrinking in size, owing to the falling in of itself, it cannot last for ever. He is quite right; we do not expect it to last for ever. When it has shrunk to a certain size its particles will

be so crowded together that it will become a solid mass, and unless there is some other force to keep it hot it will cool down. When this happens to the Sun life will become impossible on the Earth.

That is a very alarming state of affairs; but you need not be alarmed as to your own safety or that of any of your friends, nor for any of their descendants. Shrinking at the rate necessary to keep up its white heat, the Sun will last for at least ten million years yet. But you will not be able to picture any time so long as ten million years; it will only mean to you a very long time. It will seem to you a very long time since Christ lived upon this Earth, and yet it is only two thousand years ago. It is a longer time since old Abraham, Isaac and Jacob lived on this planet, but even these ancient people lived only about four thousand years ago. The people who follow us four thousand years after this will not be able to detect any difference in the size of the shrinking Sun; it is such a huge mass. How then can we tell that it is shrinking?

We can see no difference in the size of the Sun during the time that measurements of it

have been taken. But we have considered all the possible ways whereby the Sun's heat might be kept up, and the idea of the Sun shrinking gradually is the only reasonable method which can account for the results.

There is one thing we should keep in mind when we are thinking of these falling particles in the Sun. You remember how everything possessed so little weight at the Moon, because the Moon, being so much smaller than the Earth, could not attract things with nearly so much force; a twelve-stone man weighed only two stones. But in the case of the Sun it is quite the other way about; the Sun has a much greater attractive force, because it is so much more massive than the Earth.

If the postman were to hand you a dozen letters, you would have no difficulty in carrying them, even if each letter was as heavy as can be sent for one penny. But if the Earth could attract with the same force as the Sun you would find it very difficult to carry the dozen letters, as they would be as heavy as a boy of fourteen years of age.

What I wish you to notice is that if a stone were pulled down with the force of gravity

exerted by the Sun, the stone would fall with far greater energy, and there would be far more heat produced. And so you can realise that the particles in the Sun must fall with far greater energy than similar particles would fall on the Earth.

But of what are these particles in the Sun made ? You know that the word *particle* just means a very small part. So what we wish to know is, of what is the Sun made ?

If I were to tell you that the Sun is made of Iron and Copper and Zinc and Silver and Tin and Lead, you might form quite a wrong impression of the Sun. These metals are all present in the Sun, not as solid or liquid metals, but as vapours. Perhaps you never knew that metals can exist as gases or vapours ! They can ; but it requires a great deal of heat to put them into that condition. We require a great deal of heat to melt iron into the liquid state, and we require to raise the temperature still much higher to vaporise it. Of course the iron will only remain a vapour, or a liquid, so long as the necessary temperatures are kept up.

One boy asks if there is no Gold in the Sun, another asks if there is no Mercury, while a

third asks if there is no Brass. Astronomers have not detected any Gold or Mercury in the Sun, but it is possible that both these metals are present. The boy who asked about Brass must have forgotten that Brass is not a natural substance ; man makes it by melting Copper and Zinc together. If it were possible to drop a piece of Brass into the Sun, it would become Copper and Zinc vapours.

But you are not to think that the Sun is all metallic vapours. There is a great quantity of hydrogen gas, and we have found no less than forty different elementary substances in the Sun. But no one has ever been to the Sun, so how can the astronomers tell all these things ?

By examining the light sent out by the Sun, astronomers have been able to tell what kind of things are producing the light. They have a special instrument for examining the light. It has a long name, being called a *spectroscope*, but although it has a long name and is a very wonderful little instrument, there is nothing mysterious about it, and when you are a little older you will be able to understand how it works.

Does it not seem like a fairy tale that men

on the planet Earth can find out of what the Sun is made, although they are millions of miles away from it?

The ancients used to think that there was nothing more perfect than the Sun's spotless face. But as soon as the telescope was invented great spots could be seen on the face of the Sun. In ancient times people had to be very careful what they said about the Sun. One old Greek philosopher was put in prison because he said that the Sun was a huge ball of fire, and that it was possibly as large as his own country of Greece. But why should old Anaxagoras have been sent to prison for making such an apparently innocent remark? You and I could say what we like about the Sun, the Moon, or the Stars, and we should certainly not be sent to prison because of our remarks.

The real reason of the old philosopher's imprisonment was that his remarks interfered with the religious beliefs of these ancient people. In those days the Sun was worshipped in connection with their imaginary god, Apollo, who was a great favourite.

When Galileo was sent to prison, some three

hundred years ago, for trying to prove that the Earth went round the Sun, the reason of his imprisonment was the same ; his ideas seemed to clash with the teachings of the Holy Scriptures. But Galileo's answer to that was good. He said that the Bible was not intended to tell us how the heavens go, but how to go to heaven.

We were talking about the spots on the face of the Sun. The Chinese had noticed these long, long before the invention of the telescope ; indeed hundreds of years before the time of Christ. What then are these spots on the Sun ?

The sun-spots look like huge black patches. You would think you were looking through huge holes in the bright surface of the Sun into a dark centre. The spots are really holes in the Sun's outer envelope, but they look black only by comparison with the bright surface ; they are really brighter than an electric arc lamp. If some great giant electric lamp could be placed on the surface of the Sun, the dazzling electric light would appear as a patch of darkness, simply because of the great contrast with the intense brilliancy of the Sun. And so you

see that those black sun-spots are by no means darkness. How large are these spots ?

The smallest sun-spots are probably not less than five hundred miles in diameter, but there are many of these great holes in the Sun's surface so large that this planet Earth upon which we live could pass quite easily through the gaping mouths of these sun-spots. Indeed some spots have been found to measure nearly one hundred thousand miles in diameter. Are these spots always there ?

There are always some spots on the Sun, but not the same spots ; some close up, and others open. A sun-spot may last only a few weeks, and keep changing its shape every day. Every eleven years there is a special outburst of spots, and at such times they are very much more numerous than usual. These outbursts of sun-spots, although millions of miles away from our Earth, have a disturbing effect on our electric telegraph instruments. At these displays of sun-spots we have what we call a magnetic storm in the Earth.

You have no difficulty in realising that the Sun is hot; but how hot is it ? You know that it must be very hot, for, even in our cool

climate, you have found it too warm on some cloudless and windless day in summer. You may have suffered from blisters, on the arms or legs, caused by the great heat of the Sun.

You know that the Sun's heat may set things on the Earth on fire. This may be done very easily by gathering the rays of the Sun to meet at one point. We can do this by passing the sunlight through a large magnifying-glass. We call this bringing the Sun's rays to a focus. Even steel may be melted if sufficient of the Sun's rays are focused upon it.

But such burning-glasses are not safe toys for children. I remember the case of a boy who set a chemist's shop on fire by focusing the Sun's rays on some article in the window.

Burning-glasses are used in observatories for giving a record of the hours of sunshine. The Sun's rays burn or scorch a line along the centre of a cardboard record.

When I tell you that the temperature of the Sun's surface is somewhere about 7000° on Fahrenheit's scale, you cannot realise what that heat really is. Boiling water is only 212°, and boiling or molten lead is a little over 600°. Molten iron is less than 3000°, but

even that is far short of the temperature of the Sun.

I have watched the workmen at a furnace of liquid steel. I have seen them throwing heavy lumps of iron ore into the great bath of molten metal; it looked like a sea of gold. As each piece of material was thrown in the white-hot liquid metal splashed up, just as you have seen water splash when you threw a stone into a pond.

If it were possible to raise that furnace to the same temperature as the Sun, all the liquid metal would become iron vapour. You know that if you leave a kettle of water boiling for a long time the water will all escape from the kettle in the form of water vapour. You know also that if you place a cold spoon in the heated water vapour as it leaves the kettle there are drops of water deposited on the spoon. You have no doubt that the water particles really do exist in that vapour. The particles of iron do just as truly exist in the iron vapour which is one of the ingredients of the Sun. That is the condition in which all the metals exist in the Sun.

We can scarcely imagine what an intensely

hot furnace the Sun is, and yet a very eminent astronomer, who lived about a hundred years ago, believed that the Sun was inhabited by human beings. Of course he knew that the Sun was hot, but he did not know how hot it was. He knew, however, that the surface of the Sun was not only too hot to live on, but also that this surface was composed of clouds of glowing vapour. He did not picture people living on this surface, but on a cool, solid ball beneath these clouds. He thought that the inhabitants of the Sun received light and heat from this glowing envelope which surrounds the Sun.

Our present-day picture of the Sun is very different from the one which that great astronomer had one hundred years ago. (I know an old lady of ninety-eight years of age, and she was a girl of five years of age when that great astronomer died, so a hundred years ago is not so very long ago.)

We believe the whole of the Sun to be at an intensely high temperature. We cannot see anything of the Sun except that great envelope of glowing gases, which we call the *photosphere*, which means the light-giving sphere. Out-

side this is another envelope of cooler gases, and outside that again is a third shell or envelope of gases, chiefly hydrogen gas, which envelope is called the *chromosphere*.

When we speak of the envelope of cooler gases, which forms a layer between the photosphere and the chromosphere, we are not to picture a layer of cold gases ; all three coatings or envelopes are extremely hot, but the photosphere is the hottest and we see it shining through the two other coatings.

The chromosphere of glowing gases is in constant agitation, like a stormy sea, and we shall see, in the following chapter, how we know this. We shall see also that there is a fourth shell or envelope outside the chromosphere.

CHAPTER XII

MORE ABOUT THE SUN AND THE MOON

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IF I tell you that we learn something more about the Sun during an eclipse, you may wonder what an eclipse of the Sun is. I think you must have heard of such a thing; there was one seen from Great Britain a few years ago; it was in 1912. But what is an eclipse of the Sun?

You know that the Moon travels right around the Earth each month. When it happens to pass right between us and the Sun, it is said to eclipse the Sun. If the Moon covers the Sun's face completely, we speak of such an event as a *total eclipse* of the Sun.

Sometimes the Moon does not pass directly between us and the Sun, so that it covers only part of the Sun's face; we call such events *partial eclipses*. But as a general rule neither of these things happen, for the Moon passes above or below the Sun, and does not cross his face at all. On these common occasions we have merely a new moon.

Someone asks how often the total eclipses do occur. There is a total eclipse of the Sun, not every month, but about every two years. It is only total in some places, and it happens sometimes that these points are in most inconvenient places.

One boy says that he does not see why there should not be a total eclipse every month. There would be if the race-course of the Moon were on what you might call the same level as the Earth's race-course. But these two race-courses or orbits are placed like two hoops tilted at an angle to each other.

The eclipse of the Sun in 1912 was only a partial eclipse so far as Great Britain and Europe were concerned. Although it was almost total in Paris, the astronomers who wished to see the real total eclipse had to travel to some of the islands in the South Pacific Ocean.

On some occasions astronomers have had to travel to Japan, India, North America, South America, Spain, Africa, and even right round the Earth to Tasmania, in order to see the real total eclipse of the Sun. But why do the astronomers go to all this trouble and expense ?

THE MOON HIDING THE SUN

When the Moon passes in between the Earth and the Sun it hides the Sun from us and we call such occasions "Eclipses of the Sun."

Imagine making so long a journey to see an event which lasts only two or three minutes! From the time the Moon begins to pass over the Sun's face till the time it clears at the other side is about two hours, but the only time that is of use to the astronomers is when the whole Sun is covered, and that never lasts more than a few minutes.

One boy says that he cannot see how the astronomers can learn anything about the Sun when it is hidden completely by the Moon. This is quite a reasonable thought. The astronomers cannot learn anything about the bright, shining photosphere during an eclipse, for it is hidden completely, but other things outside of that, which are invisible at ordinary times because of the brilliancy of the photosphere, become visible to us when the glare of the Sun is shut off.

A total eclipse of the Sun is a wonderful sight. Great vivid red flames of hydrogen gas shoot out from the chromosphere, which you will remember is composed chiefly of hydrogen gas. We call these great flames "prominences," and you will be surprised how far these flames do shoot out.

I think I could safely offer you a prize if you could guess how long some of these flames are. One girl guesses a million miles, but she is evidently too intent on winning the prize. Imagine a flame that would stretch four times as far as from the Earth to the Moon !

One boy suggests that a flame a mile long would be enormous, but he is willing to say five miles ; another boy says fifty miles, while a girl is willing to risk one hundred miles, though on second thoughts she is inclined to reduce that figure. But even this girl is not bold enough ; indeed the girl who guessed a million miles was much nearer the truth, although her estimate was ten times too high. Some of the flames have measured over one hundred thousand miles in length, and others have reached almost half as far again, which means more than half-way from the Earth to the Moon. It is very difficult to think of a flame measuring a distance equal to almost six times round this Earth.

Another thing that the astronomers see during a total eclipse is that there is still another shell or envelope outside the chromosphere, which we have seen is composed of glowing

hydrogen gas, and from which the prominences shoot forth. This further envelope is not unlike a great halo of pearly light, only it is much more irregular in shape, and extends outwards at least a million miles around the Sun. It is called the *corona*, which means something resembling a crown. But of what is this corona made ?

Astronomers are not very sure what the corona is, but they believe it to be a great cloud of meteoric dust. Some of this very, very fine dust seems to be white-hot, and therefore shining by its own light, while the parts of the halo farther out appear to be cooler, and therefore can only reflect the Sun's light. But you will remember that the corona can be seen only during an eclipse of the Sun. At all other times the corona's light is quite invisible, owing to the glare of the Sun, and the scattering of the sunlight in our atmosphere.

Is it not a very strange thing that the Moon happens just to cover the face of the Sun exactly ? You know how very much smaller the Moon is than the Sun, and you know how near it is to us compared to the Sun. If the Moon were nearer to us or farther from us it

would not exactly cover the Sun. It is worth while making a little experiment on your own account, to show you what a strange thing it is that the Moon exactly covers the Sun.

Hold up a penny between you and the round face of a clock, or any other round object. Close one eye and look at the round object with the other eye. Then bring the penny right in the line of view between your eye and the round object. Hold the penny in such a position that you can still move it farther from you and nearer to you. Move about until you get the penny to cover the object exactly. Now move the penny farther from you and you can see the round object with the dark penny in the middle of its face. You can bring the penny towards you again until it covers the object exactly, and then, if you bring the penny still nearer to you, it will cover far more than the clock-face or other round object.

When you think of the Moon covering the Sun so exactly as it does in a total eclipse, you will think of this experiment with the penny, and you will see what a remarkable thing it is. The experiment with the penny will show you

the meaning of another kind of eclipse of the Sun, which happens sometimes.

There are certain eclipses of the Sun which are of very little use to astronomers, owing to the Moon failing to cover the Sun exactly. The Sun's bright photosphere shines out all round the dark circle of the Moon, and because of this glare the flaming prominences and the halo-like corona cannot be seen.

You can tell how it is that the Moon is too small, at such times, to cover the Sun; you know that when you moved the penny farther from you it failed to cover the clock-face. But does the Moon really go farther away from us on such occasions? It does; and the reason of this is not far to seek.

You know that the Moon's race-course is not exactly circular; it is like a circle pulled out a little at two ends. It is slightly oval-shaped; we call such a shape an *ellipse*, which word has no connection at all with eclipse. The word ellipse means a shape *coming short* of a circle. All the planets travel round the Sun in elliptic race-courses.

If you draw an oval-shaped race-course, and exaggerate the ovalness of the shape, you will

see that when the Moon travels round the Earth the Moon will be farther from the Earth while it is passing those parts of its course represented by the ends of the ellipse. And so you will see how it is that the Moon is sometimes farther from us, and when a central eclipse of the Sun occurs at such a time the Moon fails to cover the whole of the Sun, and we have what is called an *annular eclipse.*

You know that when something happens every year we say that it happens annually. But this word *annular*, in connection with eclipses, has nothing whatever to do with the word annual. Annular eclipses do not happen once a year. The word annular means a ring-shape, and it is because the Moon leaves a ring of sunlight during an eclipse that we call such an event an annular eclipse.

It is fortunate that all eclipses are not annular, or we should never have found out about that great halo-like corona. You can see how valuable a total eclipse of the Sun is to astronomers. They spend months preparing the necessary instruments for examining the flaming prominences and the corona. All the assistants are well drilled in the work they

have to do, during the few minutes of total eclipse, for every moment is of value. They go, if need be, to the other ends of the Earth, and after all this it may happen that some unsympathetic clouds get right in between the astronomers and the Sun, at the very time when the Moon is producing the total eclipse. It must be very trying indeed!

Perhaps you remember the partial eclipse of 1912. It was interesting to see the dark Moon pass over the Sun's bright face. It was curious to see the Sun in the form of a crescent moon. Several friends sent me photographs which they had taken of the partially eclipsed Sun, and these might have been mistaken for photographs of the crescent moon.

It is about a hundred years since a total eclipse of the Sun has been seen from Great Britain, but there will be such an occasion in 1927. Of course the real total eclipse will be seen only from a narrow belt of country, and this will be in Lancashire and Yorkshire.

Very few of you can hope to see the eclipse which will follow the one of 1927, as it will not occur until 1999. It will be seen as total by the people stationed in Cornwall.

Your chances of seeing an eclipse of the Moon are much surer. You have, no doubt, heard of eclipses of the Moon.

What is an eclipse of the Moon ?

I think you could guess how the Moon is eclipsed, even if you have never thought of the subject before. What could shut off the light of the Moon ? One girl suggests that the Sun comes between us and the Moon. That is a very bad guess ; the girl has forgotten for the moment that the Sun is millions of miles farther away than the Moon. If the Sun could come as near to us as the Moon, we should be burnt alive. It is quite impossible for the Sun to come between us and the Moon ; it cannot be the Sun which hides the Moon from us during an eclipse of the Moon.

A little fellow guesses that it is one of the planets that comes between us and the Moon, but he forgets how far away the planets are. None of the planets could come between us and the Moon ; even the asteroids could not, as they are millions of miles away. This little fellow says that nothing can come between us and the

THE EARTH CASTS ITS SHADOW ON THE MOON

The crescent of the Moon is not produced in the same way as the Eclipse of the Sun, shown in another illustration. Here we see an "Eclipse of the Moon," about which you will read on page 198.

Moon. He is quite right. How then is the Moon's light shut off ?

Let us make a very simple experiment. It will be so simple that you can follow it quite well in your imagination. Picture one lamp in a room that would be otherwise dark. We place a ball, or any small object, at some distance from the lamp, but where we can see it by the light of the lamp. But how do we see it ? Because the ball, or other object, reflects or sends back some of the light sent out by the lamp. Now I hold a round plate between the lamp and the object ; I cannot see the ball any longer, as it is now in the dark.

Now that is just what happens in the case of the Moon. We see the Moon because it reflects or sends back to us some of the light sent out by the Sun. But it so happens that the Earth sometimes steps in between the Sun and the Moon, and the Moon is left in darkness.

During such an eclipse of the Moon, we see the shadow of the Earth creep gradually on to the face of the Moon, until the Moon is entirely in the shadow. Here we have a proof of the roundness of the Earth, for we see its round shadow cast on the face of the Moon.

An eclipse of the Moon cannot occur more than once in six months. One boy asks why the Moon is not eclipsed every month. As the Moon circles right round the Earth every month, it must have the Earth between it and the Sun once every month. This boy has forgotten what I said about the Moon's race-course or orbit being tilted at an angle to the Earth's orbit. This causes the Earth to miss getting exactly between the Sun and the Moon every month.

Summer and Winter

One boy asks how it is that the Sun sends more heat to us in Summer than in Winter. It is very evident that the Sun is much higher in the sky in Summer than it is in Winter. It is evident also that the Sun shines down upon us for a much longer time each day in Summer than it does in Winter.

You know that if you let the rays of heat from a fire fall directly on you, you feel the heat much more than when you are to one side of the fire and the rays fall upon you at an angle. You know also that if the fire is only

kept burning for an hour or two the room is not nearly so warm as when the fire is kept blazing away all day.

In Winter the Sun is always low in the sky, its rays reach us at a considerable angle, and it does not remain long in the sky, thus producing a short day with little time at its disposal to heat the Earth.

In Summer the Sun is so much higher in the sky that it sends its rays more directly to us, and it remains in the sky a much longer time than in Winter. You can have no difficulty in seeing how it is warmer weather in Summer than it is in Winter, and you can imagine Autumn and Spring being midway between these two extremes. During these times the Sun is neither so low as in Winter or so high as in Summer.

The Sun seems to climb up gradually in the sky from Winter to Summer, and to fall again from Summer to Winter. Of course it is really the Earth that moves and not the Sun. If the Earth were spinning like a top in an upright position to its race-course, there would be no seasons at all; the Sun would be at the one height always. In this case the rays of the

Sun would reach us always at the same angle, and the Sun would heat us as long and as much at one time as at another.

The Moon does spin round in this upright position and it has no seasons. But the Earth is lying over at an angle, with the result shown in the accompanying drawing.

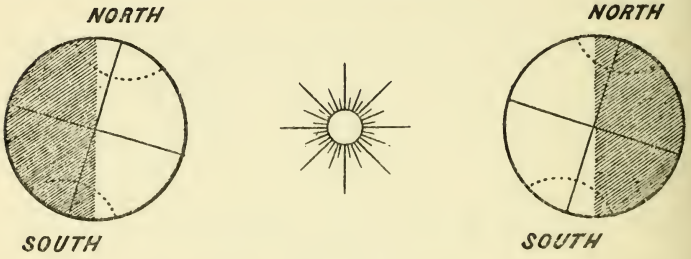

FIG. 9.

It is Summer in the North and Winter in the South

It is Winter in the North and Summer in the South

The upper dotted line represents the different positions of Great Britain as the Earth turns round each day. The light represents day and the dark represents night. Note the long day and short night in Summer, and the reverse in Winter. The lower dotted line represents the different daily positions of some place in the South, say New Zealand, or South Africa, or South America.

Here you see the Earth in two different and opposite parts of its great race-course around the Sun.

The Earth remains leaning over at the same angle all the time, but it changes its position towards the Sun. At one part of its great race-course it has its North pole towards the Sun, and when it gets round to the opposite

side of the Sun the South pole is then nearer to the Sun. That is why our friends in Australia are enjoying Summer and basking in the Sun while we are wrapping ourselves up to keep out the cold wintry weather.

Aurora Borealis

The frontispiece, which is the picture opposite the title-page, shows you what an Aurora is like. You will never see such a beautiful one while you are in Great Britain, but the people living nearer to the North Pole do see such effects constantly. Similar displays occur at the South Pole, in which case the effect is called an "Aurora Australis," while the same thing in the North is called an "Aurora Borealis." But what is an Aurora? It is a display of beautifully coloured lights due to a movement of Electricity in the upper regions of our own atmosphere.

Now we must hurry on to have a talk about the stars, and, if you have not thought of the subject before, you will probably wish to ask, "What is a star?"

CHAPTER XIII

ABOUT THE STARS

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SOME of the boys propose that we should visit the stars in our wonderful flying machine, but they must have forgotten how long that would take us, even travelling with the speed of Light, which is eleven million miles per minute. It would take us about four years to reach the very nearest star, and hundreds of years, even thousands of years, to reach the more distant stars. We cannot imagine ourselves existing for thousands of years, and we would not like to imagine ourselves on a voyage through empty space even for four years.

You will remember that we thought ourselves very far away when we were at Neptune. And so we were, although we were only a four hours' run home at the speed of Light. We were on the very outermost edge of the known Solar System. And so you see that the Sun and its family party stand alone in space, the nearest neighbour to it being a star which is millions

of miles away. No! a trip to the stars would be too big a tax upon our imaginations.

What did the ancients say about the stars? They thought of them as lights fixed in a great crystal globe, or sphere, which revolved around the Earth. One of the wise men of those days of long ago declared that the stars were stones thrown up by the Earth, and that when the stones reached the upper æther they caught fire. It was this same philosopher who was imprisoned for suggesting that the Sun was a ball of fire probably about the size of Greece.

You could stand and gaze at stars for a very long time without forming any idea of what a star is. They look mere points of light; most children tell me that the stars are made of light. These children are not aware that Light is not a material thing, but merely a wave-motion in the æther of space.

When we look at a star through a telescope, although we may see it thousands of times bigger than without the telescope, it is still a mere point of light. We do not see any detail, nor are we any wiser as to what the star is, or of what it is made. But with the aid of that wonderful little instrument—the spectroscope

—astronomers are able to tell of what the stars are made.

The spectroscope tells us that a star is just a sun placed at a very great distance from us. It tells us of what materials the stars are made, and it tells us many other wonderful things about the stars, as we shall see.

We had come to look upon the stars as being fixed in space and unchangeable in appearance. But when men came to possess modern telescopes, and when they had made very careful maps of the stars, they found that some of the stars were not fixed, but were actually moving through space. The movements seemed to be very slight, but when it was taken into account that all the stars are millions of millions of miles away, it was evident that the actual movements must be very great, or we should not be able to detect them at all.

Then the spectroscope told us that not only do the stars move to the side as it were, but some of them are approaching us, while others are flying away from us.

One girl says that she hopes the stars which are approaching us are travelling at a very slow rate. She is alarmed when I tell her that

one of these huge suns is rushing towards us at a speed of more than five hundred miles per minute. This means that since you arrived on this planet, Earth, that star has travelled thousands of millions of miles nearer to the Earth. If our own Sun were travelling towards us at the same speed, it would be right bang into us in a few months' time. But we need not be alarmed about that star which is flying towards us. Even if it were making straight for us it would not be here for hundreds of thousands of years.

We can think no longer of the stars as fixtures in space, and we must not think of them as changeless in appearance. We find that some of them keep varying in their brightness. At one time they are brilliant and at another time they are quite faint in appearance; sometimes they shine many thousands of times brighter than they do at other times. Others do not vary so much. Some vary at a very slow rate, others vary in a very short period of time, but there is a constant change going on. We call such stars *variable stars*.

Another curious thing which we find by means of a good telescope is that a star, which

appears to us as a mere point of light when we look at the sky, is in reality two stars revolving round each other. The spectroscope tells us the same thing about other stars which appear to us even in the best telescopes as single points of light. We call all such stars *double stars*; the astronomer gives them a more scientific name—he calls a double star a *Binary*.

These double stars are by no means rare; it seems as though one out of every four or five stars is a double one. Indeed it may be that if we could see the stars better we should find single stars, such as our own Sun, to be more rare than double stars. For the present we cannot tell which are the most common, because so many of the stars are at such enormous distances from us that they appear single to all our means of testing them.

Now come questions from all sides. One boy wishes to know about how many stars there are altogether, and another wishes to know how far away the distant stars are. One girl wishes to know which is the brightest star, and another asks if the bright stars are nearer to us than the faint ones. The questions will keep growing and growing, unless I commence to answer them.

The boy who asked about the number of the stars asks if any one has tried to count them. If we had not made an attempt to count them we should have no idea of the number. If you were to set yourself the task of counting all the stars which you can see on a dark, clear night, you would have great difficulty, but no less than two thousand stars have been counted from Great Britain without using any telescope. That does not mean that there are only two thousand stars visible to the eye; the stars in the sky over the heads of the Australians cannot be seen from Great Britain. If you were to travel right round the Earth, you could see between five and six thousand stars without using any telescope.

If you take a look at the sky through an ordinary field-glass, or opera-glass, you will be surprised how many more stars can be seen; there are hundreds where you saw not a single one before. Astronomers can see tens of millions of stars through their great telescopes, and you remember that we can photograph many stars which cannot be seen in the best telescopes. There may be hundreds of millions of stars.

Then a boy asked how far it is to the distant stars. This was a great puzzle, not only to the ancients, but to all astronomers until about a hundred years ago. It was only about the time when good Queen Victoria came to the throne that astronomers happened to find a way of measuring the distance to the stars.

In the beginning of the present chapter I told you that the nearest star is millions of millions of miles away. That only tells you that it is very, very far away. Even when I tell you that the actual distance is about twenty-five billion miles away you cannot form any clear conception of the distance. We in Great Britain use this word *billion* as meaning a million of millions, but in America a billion is the word for one thousand of millions.

Distances given in millions and billions can only be of use to us as comparisons. You can get a much better comparison by thinking of our wonderful flying machine taking only a few hours to reach the outside limit of the Solar System, and yet requiring four years to reach the nearest star.

When I proposed the speed of Light as the best speed for our flying machine, I made this

choice because that is the way astronomers compare the distances of stars. They do not bother with the picture of a flying machine, but they say that Light would take four years to travel from the nearest star to us, and it would take nine years from another star, and it would take hundreds of years to come from another, and so on. They say that a certain star is four light years, or two hundred light years, distant.

The next question waiting for an answer is, "Which is the brightest star?" It is called *Sirius*, and is known as the *Dog Star*. Oh dear, no! it is not a bit like a dog; all stars look like mere points of light, or "like diamonds in the sky." It is called the Dog Star because it is situated in a group of stars called the *Great Dog*.

You may not know this particular group of stars, but you are almost sure to know the *Plough*, and you may know that it is part of a group called the *Great Bear*. It is very convenient to have the stars divided into groups, each group having a name, just as it is convenient to divide a town into districts. If you wish to find Mr So-and-so, and you happen to know that he lives in such-and-such a

district, you have a guide to his whereabouts. In the same way it is easy to find a star if you know which group it is in ; we call these groups *constellations*.

Mr So-and-so may have a name to his house, but the name is of no use to you unless you can find someone who knows already where the house is. And so the ordinary name of a star is no guide to you, but the stars have scientific names which do act as a great guide.

Just as Mr So-and-so's house may have a number to it to guide you, the stars of each group or constellation have one of the letters of the Greek alphabet attached to them. The brightest star in the constellation gets the first letter (Alpha), and the second brightest gets the second letter (Beta). For instance, Sirius is known as *Alpha Canis Majoris*, which means the brightest star in the Great Dog. If you know any Latin you will be able to translate *Canis Major* into *Great Dog*.

Now you will see how useful it is to have these scientific names. When you ask me the name of the nearest star, and I tell you that it is *Alpha Centauri*, you know at once that this nearest star is the brightest star in the con-

stellation of *Centaurus*. This is the Latin word for a centaur ; you may have seen pictures of a centaur, a half man and half beast.

One boy says that his father has pointed out some of the constellations to him, but he can never see any resemblance to a Great Dog, or a Great Bear, and so on. I am not the least surprised ; most of the names are very far-fetched. The ancients gave the groups of stars these fanciful names, calling them after their favourite heroes, and animals, and such-like. It requires a great effort of imagination to see any resemblance to these heroes and animals.

There are nearly one hundred different constellations, but the names of twelve must be familiar to you as the *Signs of the Zodiac*. You see these represented on silver tea-services and such-like, and the English names are these : the Ram, the Bull, the Twins, the Crab, the Lion, the Virgin, the Scales, the Scorpion, the Archer, the Goat, the Water-bearer, and the Fishes. But why are these twelve better known than most of the others ? Because the Sun appears to pass through each of these twelve constellations in turn, taking one month

to cross each of them, and thus completing the journey in one year. Of course it is not really the Sun that moves, but ourselves. As the Earth travels around the Sun, we see the Sun with these constellations as a background.

One girl says that you do not see these groups of stars at the same time as the Sun, but the astronomer sees them in his telescope.

You may picture the twelve Signs of the Zodiac as forming a sort of belt away outside of the Earth's race-course; they are placed just like the spectators at a race.

You will see that this curious word *Zodiac* is some sort of relation to our English word *Zoo*. Both words are relatives of the Greek word for an animal which is pronounced *zoön*.

There is still one more question waiting an answer. Are the bright stars nearer to us than the faint ones? That is quite a reasonable suggestion. Astronomers used to think that the brighter a star was the nearer it must be. This would be the case if all the stars were the same. If our Sun were placed at a great distance from us it would look like Sirius, the bright Dog Star, and if the Sun were placed still farther away it would appear as a faint star.

But as soon as astronomers found a means of measuring the distance to the different stars, they found that some of the faint ones are nearer than some of the bright ones.

I have told you that Alpha Centauri is the nearest star. It so happens that it is a very bright one. One girl wishes me to point it out to her, but we cannot see it from Great Britain, it is above the other side of the Earth. The nearest star which we can see from Great Britain and Europe happens to be a very faint one; one that you would have imagined to be most distant.

Another question which is sure to arise is, "How big is a star?" Some stars are smaller than our Sun, and others are very much larger. Almost all the stars that you can see without a telescope are larger than our Sun.

If you were to watch the different groups of stars any clear night, you would see that the whole sky seems to turn round, but you would know that it is really the Earth that is carrying you round. The stars must rise and set, just as the Sun and Moon do, but there are some stars which never set, because they are near the point on which the sky seems to turn. You can

see the Plough from Great Britain at any time of any clear night throughout the year, but there are other constellations which can be seen during a few months only.

One boy says that he has difficulty sometimes in picking out the Plough, for it seems to alter its position. So it does. In Spring the Plough is nearly overhead, and in Summer it has moved round to the west and is placed with its handle turned upwards, while in Winter it is in the east, and has its handle turned down. At the end of each year it is exactly where it set off from at the beginning of the year. Near to the Plough is the *Pole Star*, around which all the stars appear to be revolving.

How is it that we see the Plough in different positions at different times of the year? Because the Earth carries us through space and we are looking at the constellations from different points of view. The nightly turning round of the stars, the rising and setting, is due to our Earth turning round like a top; what we call its rotation. We say that the Earth *rotates* on its axis, and at the same time *revolves* around the Sun.

One boy asks if all the stars in the sky to-day were there when the ancients used to look up into the sky. What suggests this question to our young friend is that he has heard people speak of *new stars*.

Of course the ancients could only tell us of the few thousands of stars that can be seen with the unaided eye, for telescopes were only invented about three hundred years ago. But we know positively that new stars have appeared in the sky. How do we know this ?

A very noted astronomer, who was born in Denmark, and whose name was Tycho Brahe, saw a new star appear in the heavens. Tycho lived before the days of telescopes, but he knew the stars so well that he could detect any change.

When Tycho saw this new star, he was so surprised that he doubted his eyesight; he had to call some of his servants to come and assure him that the bright new star which he saw did really exist. He noted the exact position of this new star, so that he might watch whether it moved or not. His friends teased him about the idea of there being such a thing as a new star. He was able to point

it out to them, but probably they did not know enough about the stars to know if it were new or not. But the star began to fade away; there could be no doubt that it was a stranger. It had become so very bright that it could even be seen in broad daylight, just as Venus is seen sometimes.

In eighteen months this new star had disappeared altogether, but we must remember that there were no telescopes in those days, or Tycho might have been able to see it longer.

We cannot imagine that a new star appears suddenly from nowhere. It might be a very faint star, invisible to the eye, unless with a telescope; it might be such a star suddenly bursting forth into a brilliant star. This did happen in 1866. A faint telescopic star flared brightly in the sky, and then very gradually returned to its old faint self.

In 1901 a new star appeared in the constellation of Perseus; it was really a very faint star that became almost as brilliant as the brightest star in the sky. This happened in a few hours, and in a few days it had lost one-third part of its brightness. It is a strange thought that this star is so very distant that

the actual flare up seen in 1901, must have occurred away out in space long before you or I had arrived on this planet.

There is another kind of star, which you might be inclined to call a new star ; it is really a comet. It is a stranger in so far that it only pays a very occasional visit to our sky, but we shall hear about it when we come to take a bird's-eye view of the Universe, in the last chapter.

CHAPTER XIV

HOW WE PHOTOGRAPH THE STARS

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YOU will remember that those little planets called the asteroids were discovered by means of photography, and I promised to tell you how we are able to photograph the stars.

I had intended a different title for this chapter. I thought of "How we bring the Sun, the Moon and the Stars nearer to us," but that title contained too many words. However, it will be of interest to see how we have brought these heavenly bodies nearer to us.

It goes without saying that we have not really moved them from one place to another, but we have done something that gives the same result. How did this come about?

There is a story told of some Dutch children, who lived more than three hundred years ago, and very probably this story tells what really did happen. These Dutch children were play-

ing in their father's workshop, and they were looking through some of the glass lenses which he had made for spectacles ; he was a spectacle-maker. The children happened to place two different kinds of lenses at a little distance from each other, and when the children looked through these they saw everything as if it had come very much nearer to them ; they saw objects which were at the other end of the workshop as clearly as though they were standing close up to the objects. But what amused the children most was that the objects were all standing upside down.

The children called the attention of their father to what they had found, and it is said that he fitted up such lenses in his spectacle shop, so that his customers could see the steeple of a distant church, as though it were close at hand, and apparently standing on its head.

Some say that this Dutch spectacle-maker fitted lenses into a tube and thereby made the first telescope, but it may be that he was content to keep the lenses as an attraction to bring people to his shop.

It so happened that the Dutch were at war with the Spaniards at that time, and no use was

made of the invention. If the Dutch had possessed telescopes, while the Spaniards had none, it would have given the Dutch a very great advantage. For that reason it does not seem very probable that the Dutch spectacle-maker really invented a telescope.

But news of his toy reached Italy, and the great astronomer, Galileo, heard of this remarkable discovery. It was just the sort of thing that would be very useful to him. He could never hope to get any nearer to the Sun, the Moon, and the Stars, but if he could bring them nearer to him that would do just as well.

Galileo did not rest until he puzzled out what sort of arrangement of lenses this Dutch spectacle-maker must have used. The astronomer sat up all night thinking about the matter, and at last he did succeed in inventing a telescope.

Galileo was delighted with his new instrument, but astronomers of to-day would look upon Galileo's telescope as a very poor affair. In reality it was little better than an ordinary field-glass or opera-glass of to-day. And yet Galileo was able to see wonders. He saw that there were mountains on the Moon, that there

were spots on the Sun, that Jupiter had moons, that Saturn was of a peculiar shape, and many more wonderful things. People did not believe in what they called his "celestial novelties."

At some other time we may have a talk about Galileo and other great men who are of special interest to children, but in the present volume we must confine our attention to the Sun, the Moon, and the Stars.

How then do we manage to photograph the stars? One boy says he does not see how there should be any difficulty; why not take a photograph in the usual way. We might take such a photograph of the crescent sun at the time of one of those partial eclipses of which we spoke in the preceding chapter, but we should learn nothing from this photograph. We wish to get detail in our photographs, so we must take them through a telescope.

There are some very large telescopes made specially for photographic work; there is one at Cambridge which measures almost twenty feet in length. The photographic plate takes the place of the observer's eye, so that the light from the stars, instead of producing sensations

A Comet

The upper picture is a photograph of a comet with stars in the background. When a comet is travelling away from the Sun the sunlight forces the tail of the comet in front of it, just as a following wind forces a steamer's smoke ahead, as seen in the lower picture.

in the eye, produces chemical changes on the photographic plate.

It so happens that stars which are too faint to be seen with the best telescopes can leave their image on the photographic plate. We may examine the sky most carefully where the camera tells us that there are such stars, but the very best telescope cannot detect these invisible stars. Yet each time that we take a photograph of that part of the sky there are the invisible stars; we call them *photographic stars*, and we should never have known of their existence but for the camera.

But there are difficulties in photographing the stars, as we shall see. Suppose we try to do some photographing in our imagination. We set up a telescope and camera, and we try to take a photograph of one of the well-known groups of stars. If you have had any experience with an ordinary camera, you know that you can only take snap-shots when the light is very good, and that when it is a dark day you must give a fairly long exposure. You know that it would be useless to try to take photographs at night. It is evident that we must give a very long exposure if we are to be

successful in photographing the faint light from the stars; we must give an exposure of a few hours, instead of a few seconds, or a fraction of a second, as in ordinary photography. But one boy says he does not see any great difficulty in leaving the camera lens open for a few hours. That is not wherein the difficulty lies. Let us suppose that we have taken such a photograph, and we set about developing the plate.

When we examine our photographic plate, we do not recognise the stars; instead of clear points of light, there are strokes or streaks of light. One girl says that the stars have moved and spoilt our photograph. Of course what has happened really is that our telescope and camera have been carried round by the Earth; it is the Earth that has moved and not the stars. What must we do? We cannot stop the Earth turning round while we take the photograph.

If you were on board a steamer which was moving along at full speed, and you wished to examine a yacht which was lying at anchor, what would you do? You would look at it through a telescope. But if you kept your

telescope fixed in one position, looking straight in front of you, you would only get a passing glimpse of the yacht. If you wish to keep the view of the yacht in your telescope for some time, you must keep turning the telescope so that it continues to point straight at the yacht. We must do the same thing with our telescope and camera while we are photographing the stars. But how can we do this ?

I wonder if you have ever been in a lighthouse ! If so, you will have seen a heavy weight which is hung on a strong rope or chain, and the weight keeps falling down the high tower, just like the weights of a grandfather clock. As the lighthouse weight falls, it causes the great reflector of the lantern to turn round, so that the lamp flashes out for a moment, is then screened, and flashes out again at regular intervals.

The telescope and camera are turned round in the same way as the lighthouse reflector, but at a very much slower rate. The falling of the telescope weight is controlled by a good clock. The rate of fall is so arranged that the telescope turns round at exactly the same rate as the Earth, but in the opposite direction. This

keeps the camera pointing steadily at the group of stars.

I remember the first time that I looked through a large fixed telescope at a bright star ; it was surprising how very quickly the star passed across the field of the telescope. As you watch the stars glide past, you realise how very quickly the Earth is turning round.

CHAPTER XV

A BIRD'S-EYE VIEW

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A BIRD'S-EYE VIEW

EVEN if you had never heard the expression "a bird's-eye view," I think you could guess the meaning of it, as the phrase really explains itself. You might go to the top of a very high building to get a bird's-eye view of the town, or you might climb a high mountain to get a bird's-eye view of the surrounding country, but the best bird's-eye view of all would be obtained by imitating the bird climbing away up into the air on a flying machine.

Our present purpose is to obtain a bird's-eye view of the things about which we have been talking.

A bird's-eye view of the Solar System shows us the Sun at the centre with its family of children and grandchildren revolving around it. Close to the Sun we see the smallest of all the planets, and we remember that it is called Mercury. A little farther out we see Venus,

and we notice that neither of these two innermost planets have any offspring, or, in other words, any moons.

Revolving outside of these two planets we see the Earth with its one moon. We are surprised that this moon looks almost as large as the planet Mercury. Venus and the Earth look so much alike that we could scarcely tell which was which unless we could see which is farthest from the Sun.

Outside the Earth's race-course, or orbit, we see Mars, not much more than half the size of the Earth, and almost exactly twice the size of our Moon. We are comparing them by the distances across their diameters. We know that there are two tiny moons circling around Mars, although we cannot see them in this bird's-eye view.

There is a very much larger space between Mars and Jupiter. It looks like empty space, but we remember about the hundreds of small planets or asteroids which have race-courses of their own in that space. Jupiter is indeed a giant. We can see that if the four inner planets were standing in a row side by side they would measure only about one quarter of Jupiter's

diameter. We can see only four of Jupiter's eight moons, but the largest looks quite as big as the planet Mars. We notice also that the farthest out moon is travelling round the planet in the opposite direction to the others.

Another big space and we see Saturn, with its interesting set of rings and its nine moons. Saturn looks a great giant, but we can see that it is smaller than Jupiter.

Much greater spaces separate Uranus from Saturn, and Neptune from Uranus, both giants, but not half the size of Jupiter. We see that these two outermost planets are spinning round or rotating in the opposite direction to the others, but all are travelling or revolving around the Sun in one direction. We notice that the planets nearer to the Sun are travelling much faster than those farther away.

In order to obtain a bird's-eye view of the stars, we must go to a far greater distance. So far that we cannot see any of the detail of the Solar System. Suppose we go till we see our Sun as a mere point of light, like one of the faint stars. We are surprised at the great distance which separates this speck of light

from the next speck of light, which is the nearest star to the Earth.

Suppose we try to make a model of this view. We take a grain of sand and place it on a sheet of white paper so that we can see it. This grain of sand is to be a model of the Sun and its family party, as seen from a great distance. Where shall we place the next grain of sand to represent the nearest star? Not on the sheet of paper, although it happens to be a large one. Not in any part of the room, no matter how large it is. Not in the village or town in which we live, but fourteen miles away. That is the sort of model we must make of the stars; they are just like grains of sand separated by many miles of empty space. Even the stars which you see forming the well-known Plough are each billions of miles from each other.

Some of you children are fond of making plasticine models of things, but there is no use of trying to make a plasticine model of the Universe. You might make our Sun a mere pinhead in size, with very tiny pellets for the planets, placed at different distances from the Sun, but you could go no further. Your next

step would be to make a small pellet to represent Alpha Centauri, the nearest star, but as you have spread out the Sun and its family over a very much larger space than was occupied by the grain of sand in our first model, you must take this larger model of the nearest star to a much greater distance. Indeed you would have to leave the British Isles, and place Alpha Centauri on some far-distant part of the World.

Leaving these models alone, and looking again at the bird's-eye view of the Universe, we see a great number of patches of hazy light of many shapes. We call each of these a *Nebula*, and when we speak of more than one Nebula, we say *Nebulæ*. What is a Nebula? It seems to be composed of gas-like matter; it is certainly something very flimsy, for we can see right through it. But what surprises us most is the enormous size of a Nebula. How big are the Nebulæ?

We can only form an idea of the size of a Nebula by comparing it with something else. You remember how very large we thought the Solar System; it is thousands of millions of miles in diameter. It would take us some

hours to cross the Solar System in our wonderful flying machine, travelling at the speed of Light. Going at the same enormous speed, it would take us twenty-five years to cross some of these Nebulæ. It is an immense distance from the Solar System to the nearest star, and yet a Nebula could fill that space six times over. The size is quite unthinkable.

In our bird's-eye view of the Universe we see a great band of scattered light stretching around the sky. We have seen this great irregular band of light from the Earth on a dark, clear night; it is called the *Milky Way*, or the *Galaxy*. It is quite different from the patches of light forming the Nebulæ. The Milky Way is composed of millions of very faint stars all clustered together.

Now we wish to take another bird's-eye view from a shorter distance, so that we can see the planets of the Solar System as points of light. Not near enough to see the flare of the meteors as they dash into the Earth's atmosphere, but just close enough to watch one of the comets passing the Earth.

Look at the strange shape of the comet's race-course compared with those of the planets'!

You can see that the planets' race-courses, or orbits, are just like circles slightly drawn out at two ends as it were. But what a lot of drawing out the comet's race-course seems to have undergone; it is a long oval shape, not a bit like a circle. You would trace out such a course, if you were to run along one side of the road, and in turning back cross over to the other side of the road, coming back on that side, and then crossing in a curve again to the first side.

This long-shaped course round which the comet travels extends right away out into space; the one which we are watching goes right out beyond the planet Neptune. The comet dashes along this course, and trails a long shining tail behind it. The comet's behaviour reminds us of a boat race, in which the boats have to go a certain distance, turn round a flag-boat, then race back and turn round a second flag-boat. In our bird's-eye view of the comet's race the Sun is the first flag-boat, and Neptune is the second one. But we notice that the comet turns very abruptly as it goes round the Sun, whereas it is very wide of the mark when it wheels round Neptune,

over-shooting this second flag-boat by a long distance.

In turning round the Sun, some comets go very much closer than others, and on the outward run some comets use Jupiter as the second flag-boat, while others go right away out into space far beyond the Solar System. This means that some comets pay us a return visit very much oftener than others. Some return every few years; others are not due to return for thousands of years.

The comet which we are watching is known as *Halley's Comet.* When you are older you will read about Edmund Halley, a famous astronomer, and a great friend of Sir Isaac Newton. Halley did not discover this comet, but he discovered that it had made regular visits to our sky, and he predicted exactly when it would return. How could he tell these things ?

It was Halley's friend, Sir Isaac Newton, who suggested that comets might be travelling on regular courses around the Sun, and not be merely chance visitors to our Solar System. Halley was able to show that this comet took about seventy-five years to get once round its

great race-course. He could trace its previous visits in the old records, and he predicted that it would return again on a certain date, seventy-five years later.

Of course it is easy to prophesy that something will happen away in the distant future, after we are all dead. But although all the grown-up people of Halley's time were dead before the next visit of the comet was due, the children and grandchildren of these people did see Halley's Comet arrive back again, just when he said that it would. We ourselves saw it in 1910. On this occasion its appearance to people in Great Britain and in Europe was not brilliant, but to the people on the other side of the Earth it was a wonderful sight.

Taking another look at the comet in our bird's-eye view of the Solar System, we see a very strange thing happen as the comet turns round the Sun. The comet comes racing along with its fine flowing tail behind it, but as it comes near to the Sun its tail seems to be blown away from the Sun, and as the comet returns it flies with its tail right in front of it. It looks just like a steamer with the wind blowing the smoke straight in front of it. But

what is a comet like, and are there many of them ?

A comet is not unlike a giant rocket. It has a head and a tail, as seen in the photograph facing page 242. You will notice that its tail is very much larger than its head, but the head is more substantial. Even then the head is by no means solid ; it is made up of particles at a distance of hundreds of feet from each other. Some of these particles may be no bigger than a pin-head, while others may be the size of small rocks. They are all made of that rock-and-iron material of which we found the meteors to be composed. You remember that we found meteors supposed to be fragments of comets.

We feel sure that meteors are really fragments of comets which have failed to hold together. Two comets have disappeared from their regular courses during last century. Astronomers actually saw one of these comets break into two pieces. Although the comets have disappeared, we find swarms of meteors flying along the tracks on which these comets raced for so long. Some comets manage to hold together a very long time. How long we cannot

say, except that we can trace Halley's Comet back for two thousand years. The Chinese kept splendid records of all the comets they saw, tracing out their paths very carefully, and we find this comet, which we now call after Halley, put down in their record of the year 200 B.C.

There are about eight hundred comets on record up to the present time. Nearly one half of these were discovered before the days of telescopes. Of the three hundred comets which have been seen during the last hundred years, only thirteen of these were visible without the aid of a telescope.

And so we see that there are suns, also called stars, and there are planets circling round suns, and there are moons, which are also called satellites, which circle round the planets, and there are meteors or shooting stars flying into our atmosphere, and there are comets, and nebulæ.

When we think of this Great Universe, of which the Solar System is so small a part, and when we think what a small part of the Solar System our planet Earth is, surely we ought to feel very humble before the Creator. We feel

inclined to join with the Psalmist of three thousand years ago, and say:

"When I look up unto the heav'ns,
which thine own fingers fram'd,
Unto the moon, and to the stars,
which were by thee ordain'd:
Then say I, What is man, that he
remember'd is by thee?
Or what the son of man, that thou
So kind to him should'st be?"

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